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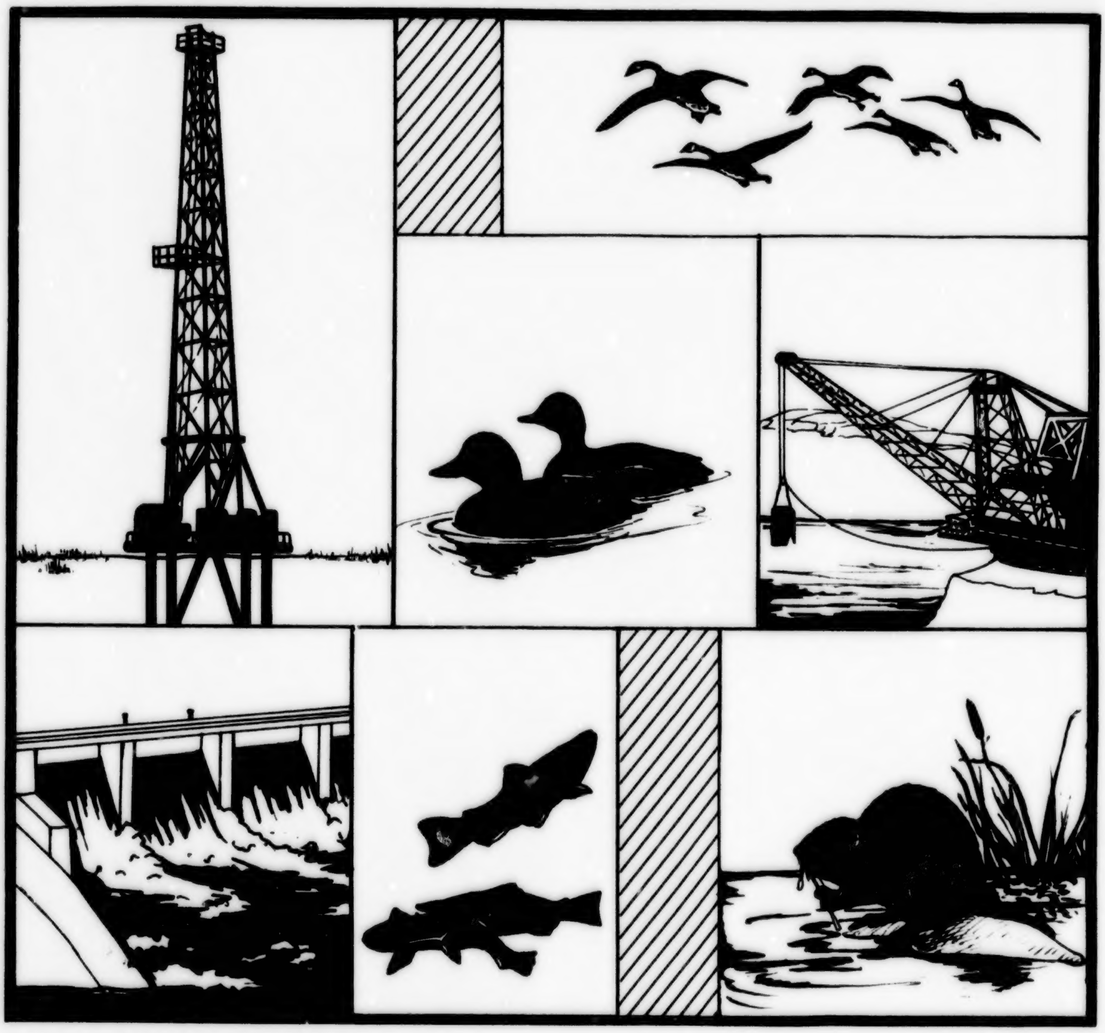
MAINTENANCE OF FLOWS DOWNSTREAM FROM WATER DEVELOPMENT PROJECTS IN COLORADO, MONTANA, AND WYOMING



Fish and Wildlife Service

U.S. Department of the Interior

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MAINTENANCE OF FLOWS DOWNSTREAM FROM WATER DEVELOPMENT PROJECTS IN COLORADO, MONTANA, AND WYOMING

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This study was funded by the U.S. Fish and Wildlife Service, National Ecology Research Center (NERC), Fort Collins, Colorado. We thank the staff at the center for guidance during the project and assistance in development of this report. We thank T. Wesche, S. Wolff, and staff at the NERC for critical review of the document.

1. INTRODUCTION

1.1 OBJECTIVE

The approach we have taken centers on identifying and describing existing projects with streamflow requirements and evaluating implementation and maintenance. Our primary objectives of this study were to:

1. identify water development projects in Colorado, Montana, and Wyoming that have streamflow requirements; and
2. assess implementation of the flow releases by analyzing streamflow data to determine how consistently streamflows are maintained.

We did not evaluate biological effectiveness of streamflow releases for two reasons. First, most projects do not have data that are appropriate for making such assessments. For many of the older projects, biological data were not collected until after construction; thus there is no standard to which present ecological conditions can be compared. Second, upstream impacts from additional developments make it difficult to isolate cause and effect relationships. The information collected in this study can be used to identify projects that might be suitable for future evaluations.

1.2 PREVIOUS STUDIES

There have been numerous publications concerning instream flow needs for fish and wildlife (Gardner and Berg 1982; Marotz and Fraley 1986), strategies for negotiating instream flows (White et al. 1980), and methodologies appropriate for determining instream flow needs (Wesche and Rechard 1980). However, there is little information concerning existing water developments that have streamflow releases to maintain downstream aquatic resources. The studies conducted by Nelson et al. (1976) and Hazel (1976) involved sampling projects with and without streamflow requirements. We were not able to identify any similar, recent studies of water development projects in the Rocky Mountains.

The Interagency Instream Flow Task Force (1979), in response to a July 1978 directive from the President of the United States, identified existing Federal developments where various aspects of instream flows (quantity, quality, flow barriers, and flow fluctuations) were considered to be a problem, and identified corrective measures. The developments did not represent the population of Federal water projects, nor did all projects have existing streamflow requirements.

Several evaluations of small hydropower projects have been conducted. The FWS (U.S. Fish and Wildlife Service 1985) conducted a follow-up study of hydroelectric projects that were reviewed by the FWS in Region 5 (northeastern U.S.). The report evaluated acceptance of FWS recommendations by the Federal

Energy Regulatory Commission (FERC) and compliance with flow releases by project operators. In 1986, FERC reviewed hydropower projects licensed in 33 States from May 1983 through April 1986 (Federal Energy Regulatory Commission 1986). Project licenses that incorporated fish and wildlife mitigation measures were identified, but implementation was not evaluated. Last, a follow-up study was conducted on five small hydroelectric projects exempted from FERC licensing in California (Brown et al. 1986).

1.3 DEFINITION OF TERMS

We have chosen to use the term "minimum streamflow" rather than "instream flow" for several reasons. Instream flow implies that a specific amount of flow has been determined necessary to maintain fish, wildlife, water quality, or other associated values. Streamflows below development projects may not represent an instream flow in this sense. Releases below development projects are a result of negotiated agreements between what Federal and State fish and wildlife agencies have determined to be necessary to maintain downstream resources and what developers are willing and able to accept. Furthermore, minimum streamflows are generally specified as an instantaneous release to be met at a specific location; flows farther downstream are not usually guaranteed. With more States adopting instream flow legislation, "minimum streamflow" prevents confusion with State appropriations for instream flow rights. "Minimum streamflow" also is more consistent with the language that is used in permits, licenses, and other agreements (e.g., minimum streamflow release, minimum bypass requirements).

The term "minimum streamflow discrepancy" is used to describe cases when mean daily streamflows downstream from a development project were below the accepted minimum streamflow amount. We have not called these situations "violations" because we were not able to evaluate all the exceptions included in the permits and licenses, nor was this our intent. From the perspective of protecting downstream resources from the impacts of water development, it is instructive to know how often the accepted minimum streamflow can be maintained regardless of various exceptions (e.g., minimum streamflow release can be reduced when reservoir storage drops below a specified amount, or outflow can equal inflows during low-flow periods). Furthermore, some of the projects we have included involve voluntary informal agreements (i.e., no binding document); thus "violation" of minimum streamflows is not applicable.

Permits, licenses, formal documents, and informal agreements that specify minimum streamflow releases are referred to as "agreements." The term "agency" describes the Federal or State agency with which there is a minimum streamflow agreement. These and other terms are described in more detail in subsequent sections.

1.4 INFORMATION PRESENTED

This report is organized according to the objectives stated above. General information is presented regarding all water development projects in Colorado, Montana, and Wyoming having minimum streamflow agreements, and additional information is presented for those projects with available streamflow data. Specific details for individual projects are not presented in the body of this report, but are summarized by project in the form of Project Fact Sheets in Appendix A (bound separately). Sources of information, including agency files and personal communications, are cited for each project in the Project Fact Sheets.

2. STUDY AREA

Water development projects with minimum streamflow requirements were identified for Colorado, Montana, and Wyoming. The general locations of projects, by State and major drainage, are illustrated in Figures 1 through 3. The Missouri River was divided into lower and upper basins because of the large geographic area covered. The North Platte River was used as the northern boundary of the Lower Missouri River basin. Similarly, the Colorado River was divided into the Green River basin and the remainder of the Colorado River basin south of the Yampa River (a tributary of the Green River).

Regional hydrologic differences among the three States are illustrated by average annual runoff and average discharge in Figures 4 through 6. Runoff is the amount of water from precipitation that is transferred along the earth's surface (overland flow) and reaches channels to become streamflow (Viessman et al. 1977). Average annual runoff is greater in Montana than in Wyoming or Colorado, thus contributing to higher discharge or streamflows. Average annual runoff and discharge are generally less in Wyoming than in Colorado, except in the Snake and Yellowstone river basins.

Water development in the Rocky Mountain region varies depending on available water resources and consumptive demands, which in turn reflect the extent of agricultural, industrial, and urban growth. Specific differences among the States are described in following sections; however, a brief summary of State instream flow legislation is instructive in defining differences among States that may influence development of water resources. Both Colorado and Montana have adopted instream flow legislation that allows the State to reserve water for fish, wildlife, water quality, recreation, and other benefits. Montana originally passed instream flow legislation in 1969 and it is referred to as "Murphy's Law." Murphy's Law allowed the Montana Department of Fish, Wildlife, and Parks (MDFWP) to file for instream flow rights on 12 high quality fishing streams (Nelson and Peterman 1979). In 1973, the enactment of the Montana Water Use Act allowed any State water to be reserved for instream uses (Nelson and Peterman 1979).

In 1973, the Colorado legislature passed Senate Bill 97, which established the Instream Flow/Natural Lake Level Program. In Senate Bill 97, water for instream flow purposes was recognized as a beneficial use, and a legal procedure was established that allowed the Colorado Conservation Board to file for instream flow rights.

The Wyoming Legislature recently (1986) recognized water for fish and wildlife purposes as a beneficial use. A summary of this legislation is not presented since it is still too new to have directly affected the projects evaluated in this study.

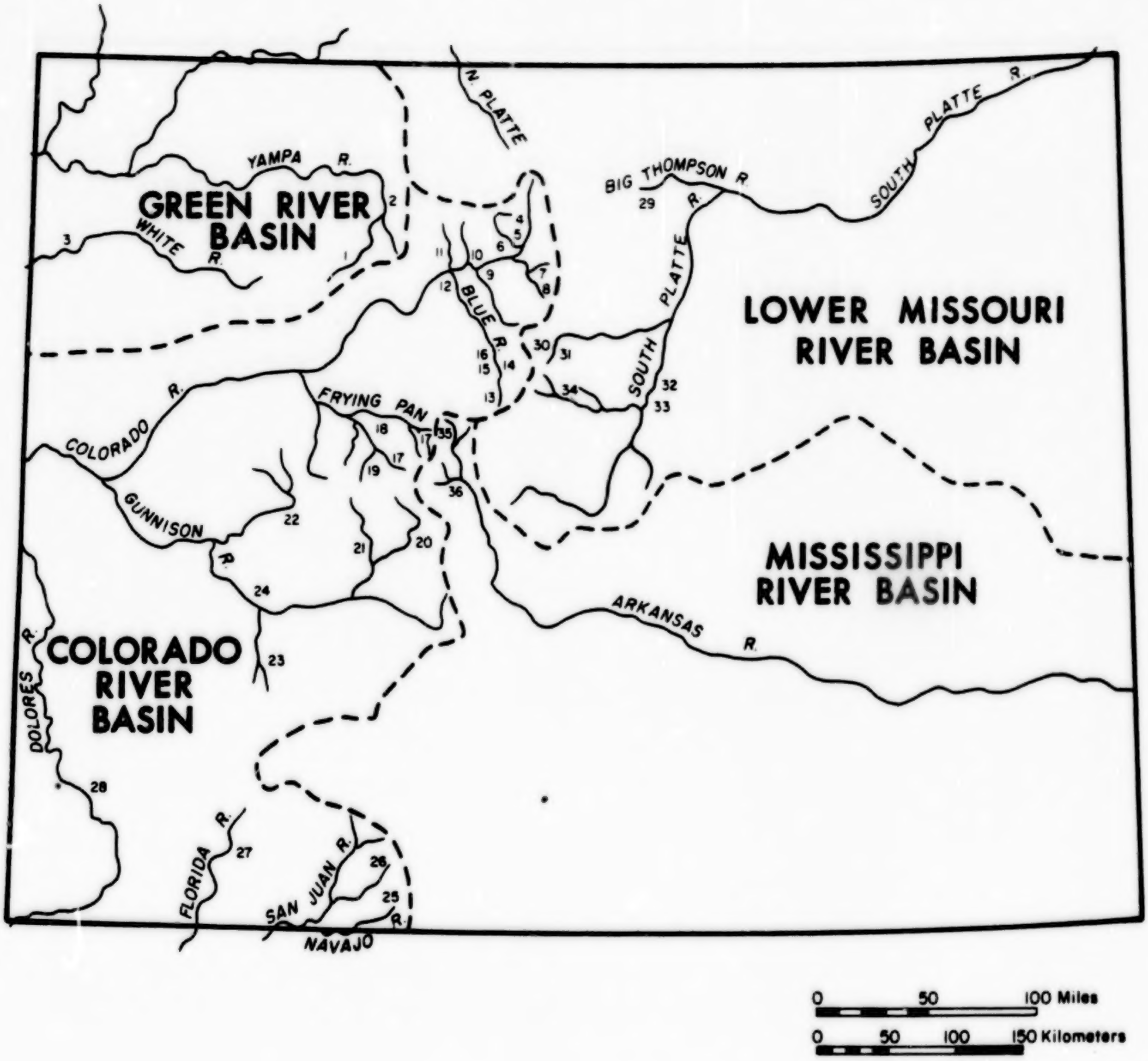

Figure 1. Location of projects in Colorado with minimum streamflow agreements.

Green River Basin

1. Yamcolo Reservoir
2. Allen Basin Reservoir Ditch
3. Taylor Draw Reservoir

Colorado River Basin

4. Shadow Mountain
5. Lake Granby
6. Willow Creek Reservoir
7. Fraser River Diversion System
8. Cabin Meadow Trans-mountain Diversion
9. Williams Fork Reservoir
10. Windy Gap Diversion Project
11. Rabbit Ears Creek Trans-mountain Ditch
12. Blue Valley Ranch Hydropower Project
13. Breckenridge Diversion
14. Keystone-Arapaho Diversion
15. Copper Mountain Diversion
16. Dillon Reservoir
17. Fryingpan-Arkansas Collection System
18. Ruedi Reservoir
19. Grizzly and Roaring Fork Diversions
20. Taylor Park Reservoir
21. Crested Butte Diversion
22. Paonia Reservoir
24. Crystal Reservoir
25. Oso Diversion
26. Blanco Diversion
27. Lemon Dam
28. McPhee Dam

Lower Missouri River Basin

29. Lake Estes
30. Urad Reservoir
31. Georgetown Reservoir
32. Strontia Springs Diversion
33. South Platte Diversion
34. Harold D. Roberts Tunnel

Mississippi River Basin

35. Sugar Loaf Dam/Turquoise Lake
36. Twin Lakes

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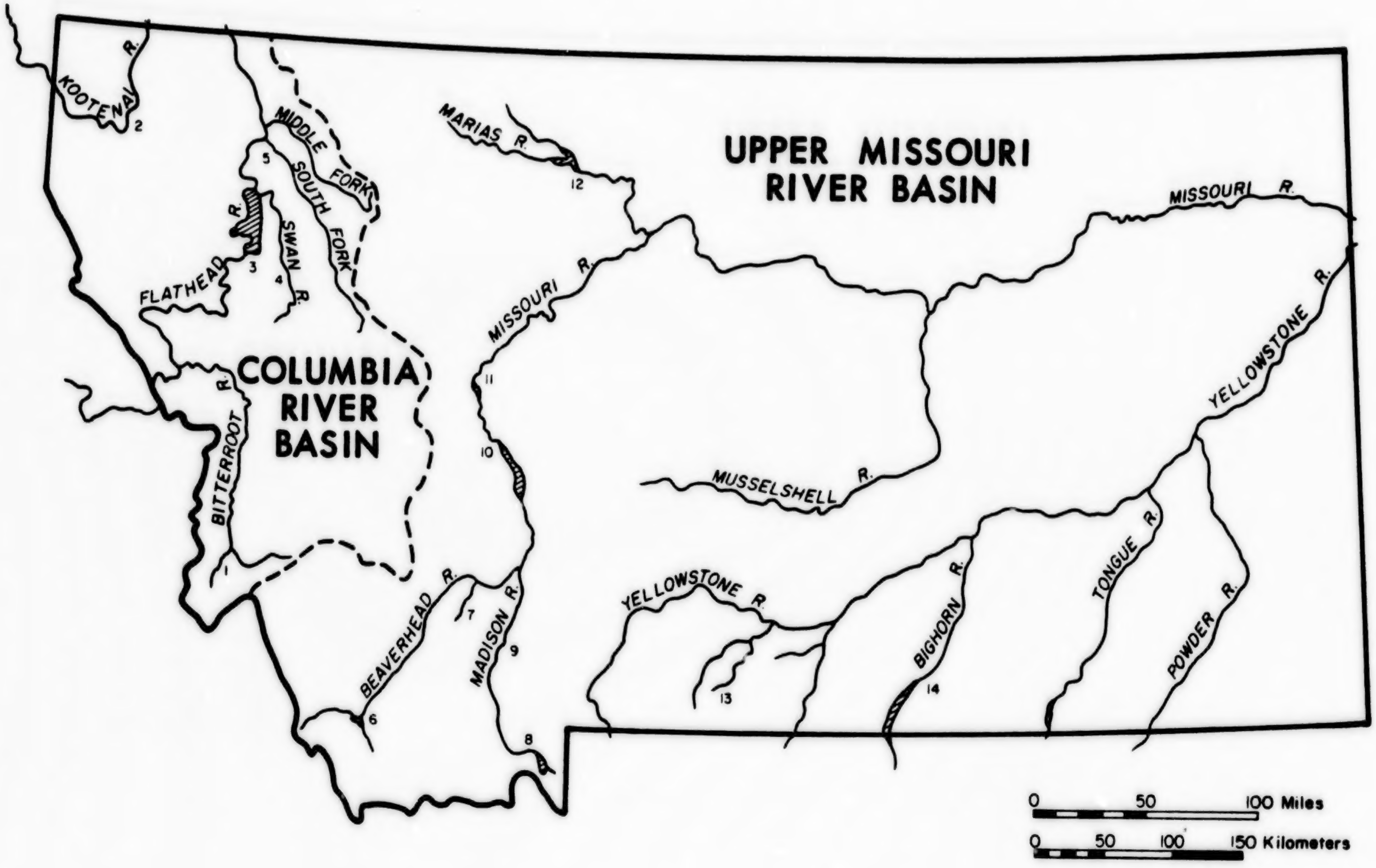


Figure 2. Location of projects in Montana with minimum streamflow agreements.

Columbia River Basin

1. Painted Rocks Reservoir
2. Libby Dam
3. Kerr Dam
4. Big Fork Hydropower Project
5. Hungry Horse Dam

Upper Missouri River Basin

6. Clark Canyon Dam
7. Potosi Hydropower Project
8. Hebgen Lake
9. Ennis Lake
10. Canyon Ferry Dam
11. Holter Dam
12. Tiber Dam
13. Mystic Lake Hydropower Project
14. Yellowtail Dam/Bighorn Lake

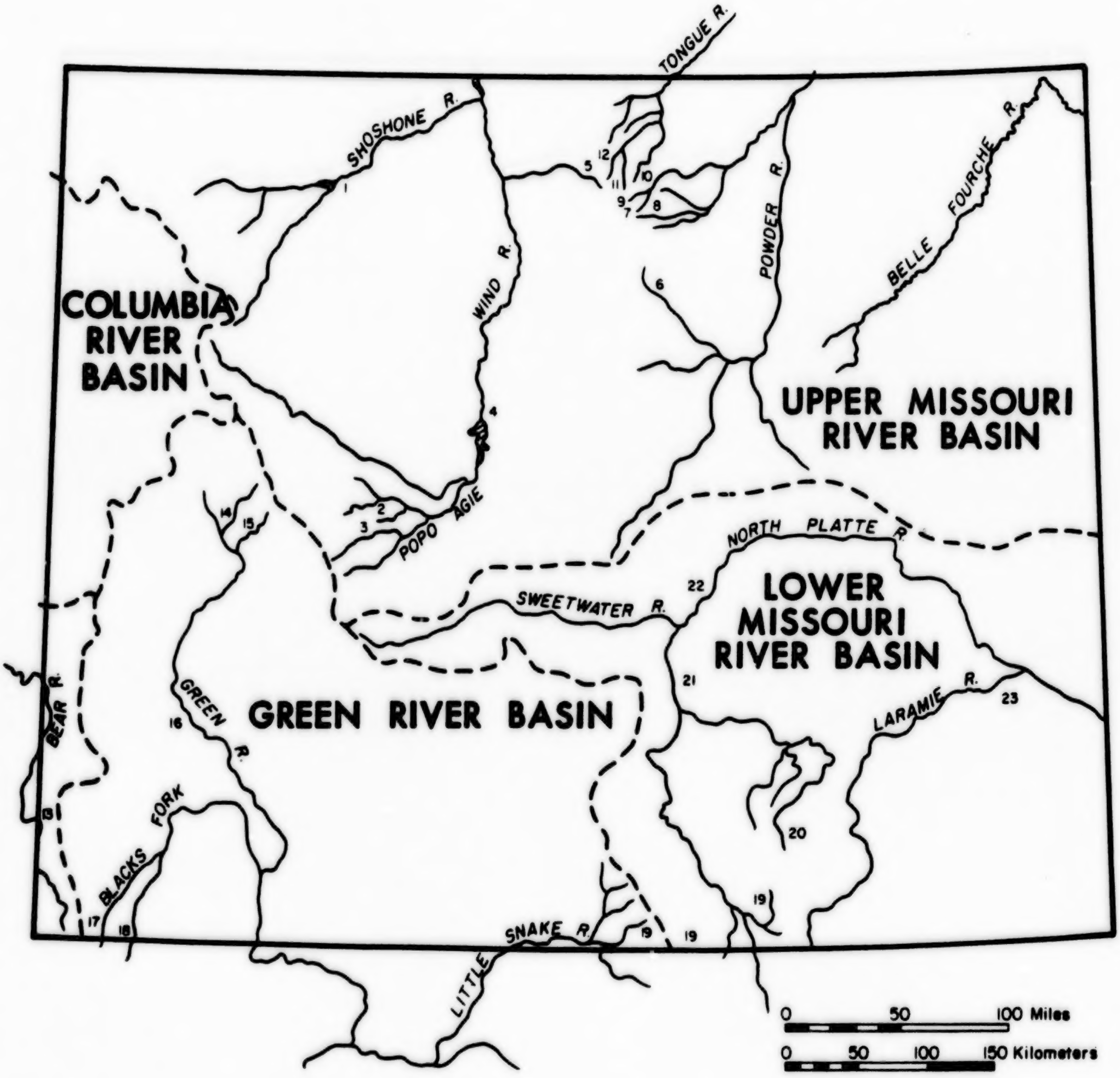


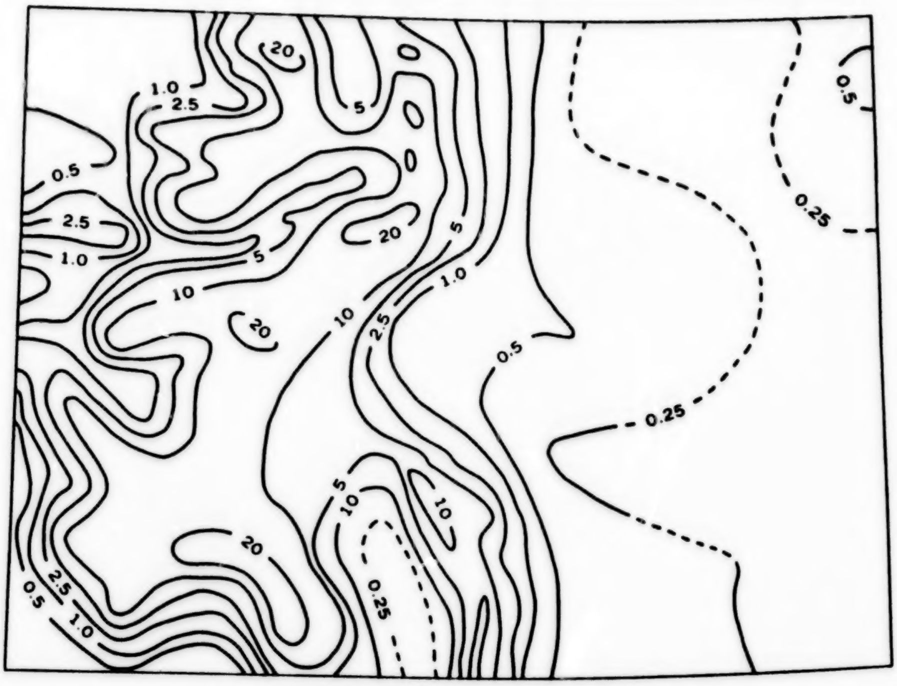
Figure 3. Location of projects in Wyoming with minimum streamflow agreements.

Upper Missouri River Basin
1. Buffalo Bill Dam
2. Shoshone Lake
3. Frye Lake
4. Boysen Reservoir/Dam
5. Shell Creek Lake
6. Dullknife Reservoir
7. Cloud Peak Reservoir
8. Willow Park Reservoir
9. Kearney Lake
10. Cross Creek Reservoir
11. Park Reservoir
12. Sawmill Reservoir

Great Salt Lake Basin
13. Woodruff Narrows Reservoir

Lower Missouri River Basin
19. Cheyenne Stage II Diversion Project

Green River Basin
14. Fremont Lake
15. Boulder Lake
16. Fontenelle Reservoir
17. Meeks Cabin Dam
18. Stateline Dam
19. Cheyenne Stage II Diversion Project
20. Sand Lake
21. Kortes Dam
22. Gray Reef Dam
23. Grayrocks Reservoir



AVERAGE ANNUAL RUNOFF, IN INCHES

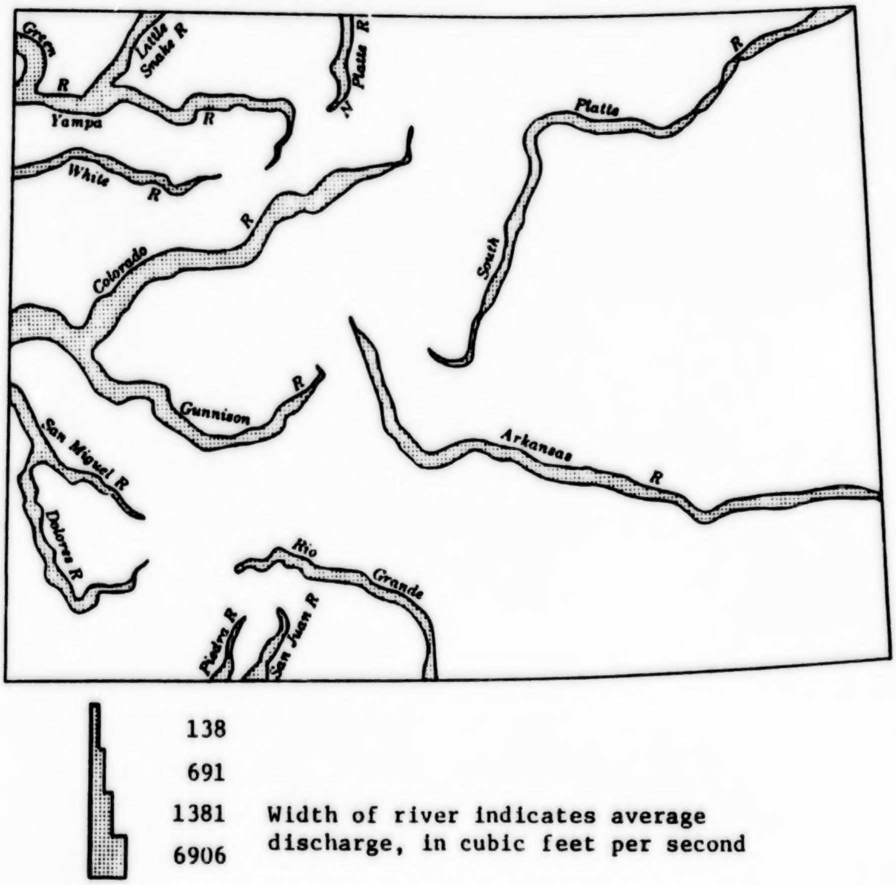
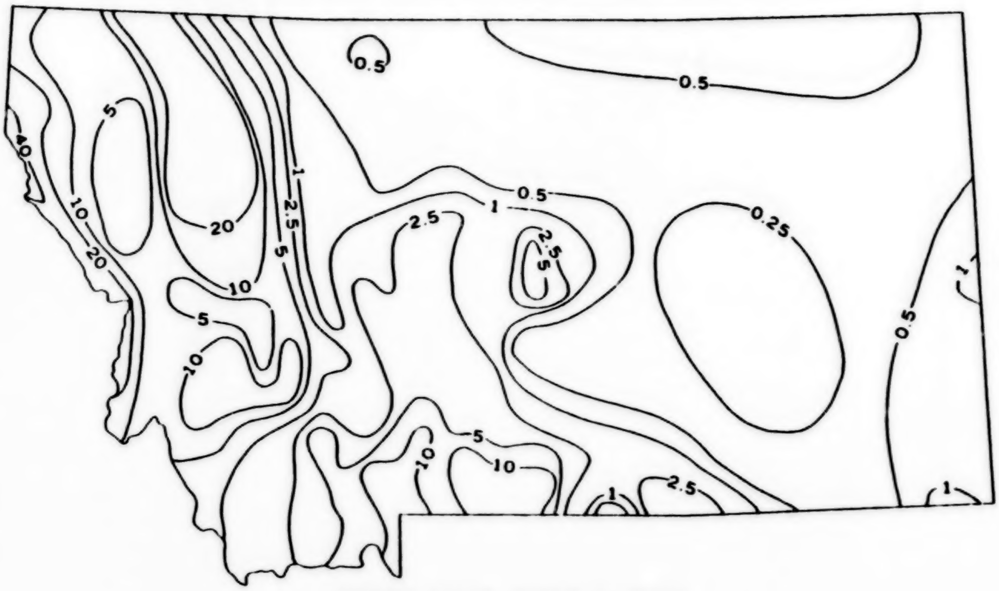


Figure 4. Average annual runoff (in inches) and average annual discharge (in cubic feet per second) for major rivers in Colorado (U.S.G.S. 1968). The scale was converted from acre-feet to cubic feet per second for comparison with discharge rates for rivers in Montana and Wyoming.



AVERAGE ANNUAL RUNOFF, IN INCHES

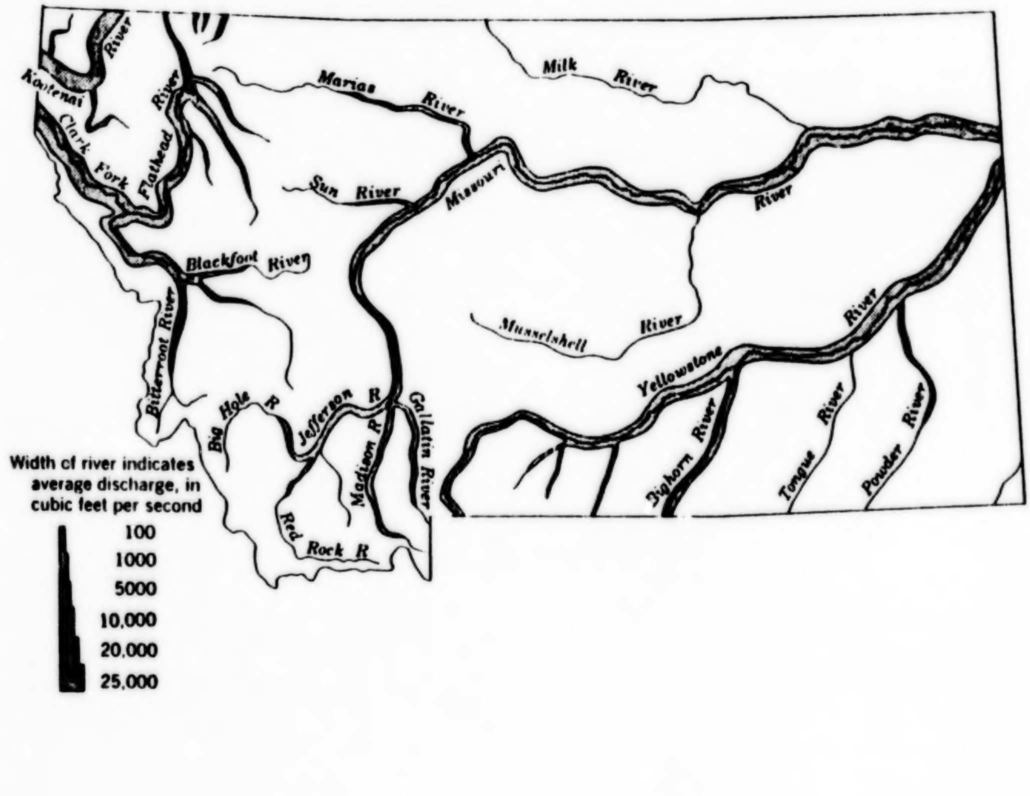
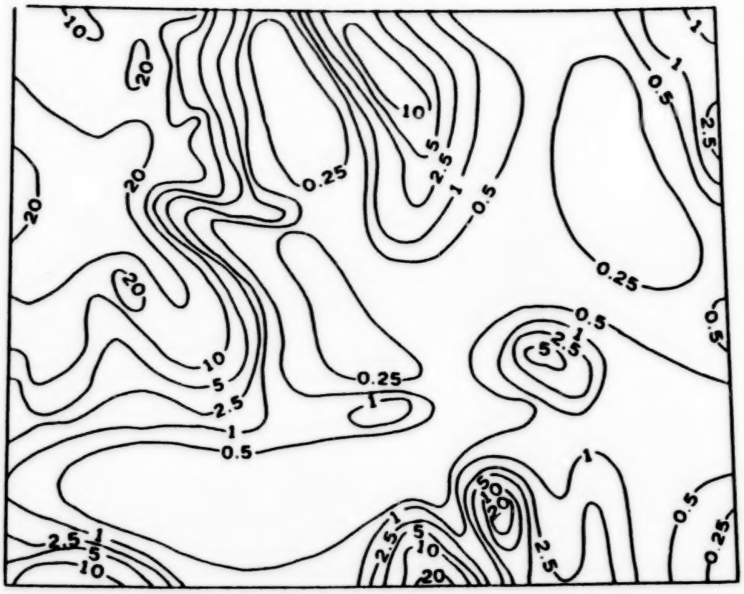
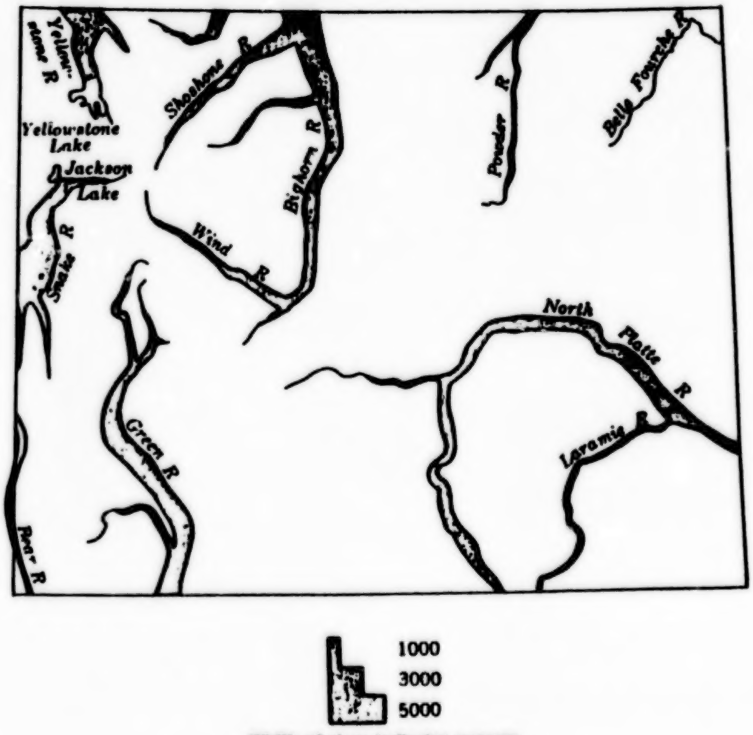


Figure 5. Average annual runoff (in inches) and average annual discharge (in cubic feet per second) for major rivers in Montana (U.S. Geological Survey 1982a).



AVERAGE ANNUAL RUNOFF, IN INCHES



AVERAGE DISCHARGE OF THE PRINCIPAL RIVERS

Figure 6. Average annual runoff (in inches) and average annual discharge (in cubic feet per second) for major rivers in Wyoming (U.S. Geological Survey 1982b).

3. METHODS

3.1 SELECTION CRITERIA

We considered three major criteria when selecting water development projects to assess implementation of minimum streamflow recommendations. First, we selected projects where minimum streamflow recommendations had been accepted by the construction agency. Consequently, the accepted streamflow releases were stipulated in a Federal permit or license, the project authorization or operating principles, or a signed (or in some cases informal) agreement between the operating agency and fish and wildlife agencies. Of these, we selected only water projects where the minimum streamflow releases were made specifically to maintain fish and wildlife habitat, water quality, or stream channel integrity. We used these criteria to avoid projects where water is released solely to satisfy downstream water rights. Last, construction of the major project features must have been completed, thus ensuring that the minimum streamflow agreements were in effect.

Projects with daily hydrologic data were needed to determine if the proposed schedule of minimum streamflow releases was followed. Consequently, once projects were selected based on the above criteria, we chose projects that had available a minimum of one year of hydrologic data. The results of the study are organized into two major sections based on the selection criteria: 1) all water development projects meeting the criteria described above and (2) water development projects with appropriate hydrologic data.

3.2 IDENTIFICATION OF CONSTRUCTED WATER DEVELOPMENT PROJECTS

Information concerning water development projects is vast and incomplete. Listings of projects with minimum streamflow releases are not available at the agency level. Therefore, our first major task was to identify all existing water projects meeting the selection criteria. Appropriate State fish and wildlife agencies, and the Federal agencies involved in construction, permitting, licensing, and environmental review of development projects, were contacted in each State (Colorado, Wyoming, and Montana respectively). Initially, biologists in the central offices for the State fish and wildlife agencies were contacted. Then biologists in the State area offices were contacted to identify known projects in their area and to collect more project-specific information.

Federal agencies were contacted on a State or regional basis. We contacted the FERC offices in San Francisco, California, and Portland, Oregon, to identify FERC licenses with minimum streamflow stipulations issued to projects in the study area. The Bureau of Reclamation (BR) is organized according to river basins; therefore we contacted both river basin regional offices and specific project offices. We contacted all national forest supervisors requesting information on water development projects; we then proceeded to contact appropriate district offices and ranger stations. The Bureau of Land Management (BLM) State offices were contacted for information on BLM permits having minimum streamflow stipulations. When necessary, we also contacted BLM Resource Area offices. FWS Ecological Services offices (now Fish and Wildlife Enhancement) within the study area and at Region 6 headquarters were contacted to help in the identification of projects and to collect project specific information. Finally, we contacted U.S. Army Corps of Engineers (COE) regulatory offices and, when necessary, Soil Conservation Service (SCS) offices.

Two additional sources of information were helpful in identifying water development projects. Nelson et al. (1976) identified some projects in the Rocky Mountain region where minimum streamflows were recommended; however, these recommendations were not accepted in all cases. Second, a map compiled by U.S. Geological Survey (U.S. Geological Survey 1984) and the Water Resources Council identified major dams and diversions throughout the United States. These two sources were not as useful as contacting individual agencies because the information was incomplete.

3.3 DATA COLLECTION AND ANALYSIS

3.3.1. Water Development Project Characteristics

In addition to evaluating streamflow data, we considered the following information pertaining to the projects and the respective minimum streamflow agreements:

1. general project information including location, construction date, construction and operating agency, type of structure (e.g., diversion or storage dam), primary use of project water (e.g., irrigation, municipal), date of the minimum streamflow agreement, type of minimum streamflow agreement (e.g., FERC license, signed agreement), and which Federal or State agency the agreement was with;
2. information, methods, or instream flow methodologies used to determine the minimum streamflow releases;
3. type of minimum streamflow release (e.g., seasonal, year round);
4. resources addressed by the minimum streamflow agreement;
5. Federal and State agencies involved in determining the minimum streamflow releases; and
6. minimum streamflow recommendations made by the FWS.

Project information was collected by interviewing appropriate agency personnel and examining project reports and correspondence files. We used this information to develop a profile of the existing water development projects with minimum streamflow agreements and to identify factors that may be related to maintenance of minimum streamflow releases. Details of specific projects are not presented in the body of this report but are summarized in Project Fact Sheets in Appendix A (separate volume).

3.3.2 Daily Streamflow Data

Once water projects were selected, streamflow gaging stations immediately downstream from the projects were identified and average daily discharge data, in cubic feet per second (cfs), were acquired. The majority of streamflow data were from U.S. Geological Survey (USGS) gages. Some data were also obtained from the BR and State sources.

Streamflow data were not available for all water development projects due to the lack of a continuous recording gage at an appropriate location. For those projects without streamflow data it was sometimes possible to acquire information as to whether the minimum streamflow releases were being maintained, but the subjective nature of this type of information prevented us from analyzing these projects in a systematic fashion.

When streamflow data from gaging stations upstream of a water project were also available, we were able to determine how often the inflow was less than the accepted minimum flow. Few water projects had both upstream and downstream flow data available.

3.3.3 Analysis of Streamflow Data

For those water development projects having average daily streamflow data, we evaluated the frequency and magnitude of minimum streamflow discrepancies. A minimum streamflow discrepancy was defined as any day the average streamflow (in cfs) was below the accepted minimum streamflow for a particular stream location. Frequency of discrepancies was recorded as the number of days during the period of record that the average daily streamflow was below the agreed upon minimum flow. Magnitude of streamflow discrepancies was evaluated at five levels (Table 1). For example, consider a project with a minimum streamflow of 100 cfs at all times. The frequency of minimum streamflow discrepancies at the first level (Table 1) would represent the number of days when streamflows below the project were less than 100 cfs. Frequency of minimum streamflow discrepancies at the second level would represent the number of days when streamflows below the project were less than the accepted minimum release by more than 10 percent, or in this example when streamflows were less than 90 cfs.

Because our main objective was to evaluate how often accepted minimum streamflow releases were not maintained, for whatever reason, our primary analysis focused on frequency of discrepancies based on downstream data. We then evaluated how often the upstream flows were less than the agreed-to minimum flow and how this might influence the frequency and magnitude of minimum flow discrepancies. Additionally, we considered the possible effect of drought periods on the frequency and magnitude of discrepancies. To evaluate this relationship we compared frequency of minimum flow discrepancies with monthly Palmer hydrological drought indices (Karl and Knight 1985).

For water development projects where minimum streamflow discrepancies existed, we collected information from the agencies and operators to try to determine the factors associated with failure to meet the minimum releases. We considered the following general factors:

(1) low inflow or low natural streamflow,
(2) operational problems,
(3) maintenance and repair of project structures,
(4) misinterpretation of the minimum streamflow agreement,
(5) too much latitude in the minimum streamflow agreement (i.e., agreement not binding), and
(6) lack of project monitoring.

Table 1. Mean daily streamflow data were evaluated according to five levels of magnitude.

Magnitude	Definition
1 = All discrepancies	Mean daily streamflows that were below the minimum streamflow requirement.
2 = Discrepancies > 10 percent	Mean daily streamflows that were below the minimum streamflow requirement by more than 10 percent.
3 = Discrepancies > 25 percent	Mean daily streamflows that were below the minimum streamflow requirement by more than 25 percent.
4 = Discrepancies > 50 percent	Mean daily streamflows that were below the minimum streamflow requirement by more than 50 percent.
5 = Discrepancies > 75 percent	Mean daily streamflows that were below the minimum streamflow requirement by more than 75 percent.

4. RESULTS

4.1 ALL WATER DEVELOPMENT PROJECTS

We identified 36, 14, and 23 water development projects having minimum streamflow agreements in Colorado, Montana, and Wyoming, respectively. We did not limit our search to projects of any particular size; thus, the identified projects vary from large-scale storage dams on major rivers, to transmountain diversion projects, to small storage dams on headwater streams.

Some of the large projects involved water diversions from several streams and, consequently, the minimum flow agreement stipulated flows for several streams or minimum flow requirements at several locations along a particular stream. Thus, the number of projects was translated to the number of stream locations having a minimum streamflow requirement. The following results, unless otherwise indicated, are presented as the number of stream locations, or simply the number of streams, and not the number of projects or minimum streamflow agreements. The number of streams with minimum flow requirements in Colorado, Montana, and Wyoming was 64, 17, and 38, respectively.

Table 2 presents the number of streams with minimum flow requirements according to State, agency, and major river basin. The category "agency" does not necessarily represent the organization that constructed or operated a particular project. For example, stream locations subject to minimum flow stipulations in BLM, U.S. Forest Service (FS), COE, or FERC permits or licenses were listed under the respective agency. Minimum streamflow agreements between a State fish and wildlife agency and a project developer or operator were listed under the subcategory "State". The Bureau of Reclamation, on the other hand, was generally the developer and operator, as well as its own regulatory agency.

For some streams there was more than one permit, license, or agreement. To avoid duplication in these cases, the "agency" was based on what we determined to be the initial or primary party that incorporated the minimum streamflow releases. All BR streams were listed under this category even though a few had additional COE 404 permits, formal agreements, or informal agreements. Streams subject to an agreement with a State fish and wildlife agency were classified under the "State" category only if there was not a Federal permit or license with the same stipulations. We chose to approach these projects in this manner because a Federal permit or license implies a Federal regulatory responsibility. More specific information on the various minimum flow agreements is presented in Table 3.

The Missouri River basin covered the largest geographic area within the study area, and the Colorado River basin the second largest geographic area. Sixty percent of all streams with minimum streamflow requirements were located within the Colorado River basin (Colorado and Green Rivers totaled), while 34 percent were within the Upper and Lower Missouri River basins.

Of the streams with minimum flow agreements, most were in Colorado; almost half of these were streams with BR projects. The BR had the greatest number of streams with minimum flow requirements for all three States combined. In Wyoming, over half of the minimum flow agreements were

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Table 2. Number of stream locations with minimum streamflow agreements by State, agency, and major river basin.

	Colorado						Montana					Wyoming						
River basin	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Columbia River							2	1	2									5
Upper Missouri River							4		3	1	4	2			9	1		24
Lower Missouri River	1	5										2			7		1	16
Great Salt Lake													1					1
Green River			1		1							3		1	10		1	17
Colorado River	27	13		1	7	6												54
Mississippi River	2																	2
Total	30	18	1	1	8	6	6	1	5	1	4	7	1	1	26	1	2	119

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

Table 3. Number of streams, by State and agency, under various forms of agreements specifying minimum streamflow releases.

	Colorado						Montana					Wyoming					
Form of agreement	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE
Operating criteria	11						5	1				5				1	
BLM permit		18											1		14		
COE 404 permit	9	1	1		1									1			
FERC license		1		1					5								
FS permit	1				8										25		
Signed agreement	1	8	1	1	4	6				1	1	2	1	1			2
Informal agreement							4				3				1		
Legislative and judicial	18						1	1	1		1	2			1		1

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

conditions of FS special use permits. We only identified one SCS project and six constructed projects licensed by FERC that had minimum streamflow requirements.

The various permits, licenses, and other agreements stipulating minimum streamflow conditions for the 119 stream locations are presented in Table 3. All the permits, licenses, and other agreements that we identified are included in Table 3; thus, the number of agreements under each agency can be greater than the number of stream locations shown in Table 2.

Minimum streamflows for BR projects were identified in the project operating principles or criteria. For some of these projects the minimum flows were determined before the project was authorized and subsequently were stipulated in the authorizing legislation. There were two BR projects, Flathead River below Hungry Horse Dam, Montana, and North Platte River below Kortes Dam, Wyoming, where provisions for minimum streamflows were legislated many years after the water projects were constructed due to concern for the downstream fishery resources. COE 404 permits stipulated minimum flows for several BR streams in Colorado, but the minimum flows had already been established and included in the project authorization (Judicial and Legislative category).

Court decisions also played a role in specifying minimum streamflows, as was the case with Grayrocks Reservoir in Wyoming (Judicial and Legislative Category). Minimum streamflows specified in the environmental impact statement for this project were not considered adequate by fish and wildlife interests and the National Wildlife Federation brought suit against the developer. The final court decision included provisions for more adequate minimum streamflow releases.

Minimum streamflow agreements with State fish and wildlife agencies usually involved signed agreements, except in Montana. The Montana Department of Fish, Wildlife and Parks (MDFWP) has negotiated several informal agreements with power companies and other developers. Specific flow releases were agreed upon, but not specified in formal signed documents. Both the department and the developers have been satisfied with these cooperative efforts and have not felt it necessary to formalize the arrangements.

The distribution of streams according to the amount of the minimum streamflow release and the type of stream structure is summarized in Table 4. We used the amount of the minimum streamflow release as a measure of stream size.

Over half of the 119 streams were small streams with minimum flows of 10 cfs or less; 70 percent of these were releases below diversion structures, while the remainder were below reservoirs. The proportion of minimum flow agreements below diversion versus storage dams, regardless of stream size, was 51 percent versus 49 percent, respectively. The majority of streams subject to BLM, FERC, and FS permits were relatively small and did not have minimum flow releases greater than 50 cfs. The majority of minimum flow releases in excess of 200 cfs were associated with BR projects. Seventy percent of all streams associated with BR projects were located in Colorado and almost half of these had minimum flows less than 11 cfs. The eight streams that had minimum flow releases greater than 500 cfs were all located in Montana, and

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Table 4. Number of streams, by State and agency, according to relative stream size and type of project structure. The amount of the minimum streamflow release (in cfs) was used as a measure of relative stream size.

	Colorado						Montana					Wyoming						
Minimum streamflow and type of structure	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
0-10 cfs	14	12			7	1			2			2	1		23	1	1	64
Diversion dam	12	11			7	1			1			0	0		13	0	0	45
Storage dam	2	1			0	0			1			2	1		10	1	1	19
11-50 cfs	8	3		1	1	2			2	1				1	3		1	23
Diversion dam	3	0		1	0	2			1	0				0	0		0	7
Storage dam	5	3		0	1	0			1	1				1	3		1	16
51-200 cfs	6	3	1			3	2											15
Diversion dam	2	3	0			3	0											8
Storage dam	4	0	1			0	2											7
201-500 cfs	2						1				1	5						9
Diversion Dam	0						0				0	0						0
Storage Dam	2						1				1	5						9
501-1000 cfs											1							1
Diversion dam											0							0
Storage dam											1							1
1001-4100 cfs							3	1	1		2							7
Diversion dam							0	0	0		0							0
Storage dam							3	1	1		2							7

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

the proportion of minimum flows below diversion dams was lower in Montana than in any other State.

Dates of minimum streamflow agreements and project construction were analyzed with respect to the chronology of major Federal and State legislation (Table 5). The dates correspond to the enactment of the FWCA in 1934 and two subsequent amendments in 1946 and 1958, NEPA in 1969, and State instream flow legislation. We did not identify any minimum streamflows that existed before 1946, but 14 streamflows (12 percent) predated 1958. With respect to construction dates, however, 20 of the minimum flows were associated with projects completed before 1946, and 31 flows were associated with projects completed before 1958. The majority of these flows were established when old hydroelectic facilities came up for FERC licensing or when older BR projects were modified. A few of the minimum flows were established as a result of State fish and wildlife agencies acquiring biological information that was not previously available and negotiating minimum flows downstream from existing projects.

Sixty-six percent of the minimum flows in Colorado were established prior to the 1973 State instream flow legislation. A smaller proportion (35 percent) of minimum flows in Montana were established before the State recognized water for fish and wildlife purposes in 1969. Additional instream flow legislation was passed in Montana in 1976. In Wyoming instream flow legislation was passed in 1986; thus, all the minimum streamflows that we identified predated State legislation in Wyoming.

4.1.1. Methods Used to Determine Minimum Streamflow Releases

It is important to realize that the accepted minimum streamflow may not have been the same amount determined by a specific aquatic study conducted or instream flow methodology applied to the stream in question. Generally, the accepted streamflow was the result of what fish and wildlife agencies determined to be necessary and negotiations with developers. Due to the poor documentation of the negotiation process, we were not able to consistently identify whether the accepted flow was the same as that determined by the use of an instream flow methodology; or was a synthesis of results from several stream studies; or was adjusted during negotiations due to such factors as operational constraints and politics. Therefore, the following categories represent information and methods used to determine the minimum flows with the recognition that other factors may have entered into the final determinations.

Biological or habitat studies: Studies that entailed systematic sampling of populations or available habitats, other than a specific instream flow methodology, were included in this category. This category included streamflows that were determined using information from electrofishing and seining surveys, creel censuses, mark-recapture studies, quantification of aquatic habitats (e.g., riffles, pools, spawning areas), or other similar methods. However, this category did not include flows that were determined from general field observations, visual estimates of population characteristics or habitat types, or professional judgement.

Observation and measurement of test streamflow levels: Studies in this category involved regulated releases of various flows followed by measurements of available habitat. These studies were conducted when a project already

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Table 5. Timing of minimum streamflow agreements and construction of projects with respect to the Fish and Wildlife Coordination Act (1936, 1946, and 1958), National Environmental Policy Act (1969), and State instream flow legislation (Colorado 1973, Montana 1969, and Wyoming 1986). The number of streams, by State and agency, is presented.

Date	Colorado						Montana					Wyoming						
	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Initial minimum streamflow agreement:																		
Pre 1946	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Pre 1958	5	-	-	-	-	-	4	-	-	-	-	1	-	-	4	-	-	14
Pre 1969	27	9	-	-	3	-	4	-	-	-	2	7	-	-	7	1	1	61
Pre State instream flow legislation	28	11	-	-	3	-	4	-	-	-	2	7	1	1	26	1	2	CO 42 MT 6 WY 38
Completion of project structure:																		
Pre 1934	-	-	-	-	-	-	-	-	2	1	3	1	-	1	-	-	1	9
Pre 1946	1	5	-	-	-	-	-	-	3	1	4	2	-	1	2	-	1	20
Pre 1958	5	5	-	-	-	-	4	-	3	1	4	3	-	1	4	-	1	31
Pre 1969	9	10	-	-	3	-	6	-	3	1	4	5	1	1	8	1	1	53

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

existed (e.g., Fontenelle and Boysen Dams, Wyoming, and Canyon Ferry Dam, Montana) and streamflows could be regulated by amount and duration.

The following three categories are based on method categories defined by the Instream Flow Studies Database (U.S. Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado).

Instream Flow Incremental Methodology (IFIM; Bovee 1982): This category included only those minimum flows that were determined by the IFIM program.

Hydrologic Based (Water supply-yield): Instream flow methodologies included in this category were the Tennant or Montana method (Tennant 1976), Q7-10 or 7-day-10-year low-flow method, and the Hoppe method (Wesche and Rechard 1980). We did not include evaluation of streamflow records in this category when specific methodologies were not employed in the analysis.

Hydraulic based (Water behavior-depth, velocity, etc.): Minimum streamflows determined from hydraulic studies were included in this category. Specific instream flow methodologies included the wetted perimeter/water surface profile methods (WSP, IFG-1, IFG-2, and IFG-4; Wesche and Rechard 1980; Trihey and Wegner 1981), and Montana's wetted perimeter inflection point method (WETP; Leathe and Nelson 1986).

Other Methods: This category included minimum streamflows that were based on professional judgement, field observations (i.e., visual estimates of population characteristics or habitat types), and streamflow records when specific methodologies were not used in the evaluation. Streamflows were classified as having been determined by "other methods" only when none of the more specific categories applied. We make this point because it can be assumed that professional judgement and knowledge of historic flows are used to some degree in all streamflow negotiations. For our purposes, we wanted to separate cases where only general information was used from cases where more systematic approaches were applied.

Undetermined methods: This category included minimum streamflow determinations for which specific information or methods used could not be identified.

Sometimes more than one method was used to determine a minimum streamflow, thus the number of methods used may be larger than the actual number of minimum streamflows (Table 6).

There were four minimum streamflows for which we were not able to identify the information or method used. These streams were located in Wyoming and all had FS special use permits issued between 1955 and 1961. More than likely professional judgement and available information on historic flow conditions were used. Based on information from the Wyoming Game and Fish Department (WGFD), it is doubtful that biological data for these streams existed at that time.

Forty-five of the minimum streamflows (38 percent) were determined using other methods. Of these, 31 (67 percent) were determined prior to 1969. Of all the minimum streamflows, the earliest use of an instream flow methodology (R-2 Cross method) was in the mid 1960's. Fifteen percent of the minimum

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Table 6. Methods used to determine minimum streamflow releases.

	Colorado						Montana					Wyoming						
Method	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Biological or habitat survey	26	1	1			3	3	2	1						16		1	54
Observation of test flow levels	2						3				1	4						10
IFIM		1				2												3
Hydrologic based	15	1					1		2			2			3			24
Hydraulic based	15	2	1		5	6	3		2		2	2			16		1	55
All other methods	6	16		1	3		3	1	1	1	2	3	1	1	4	1	1	45
Methods undetermined															4			4

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[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

flows determined by other methods not only had minimum flow agreements post-1970, but also were subject to BLM right-of-way permits.

Hydraulic methods were used widely across all States. In Colorado, the Division of Wildlife Resources (CDWR) regularly employed the R-2 Cross method. In Montana, the MDFWP frequently used the wetted perimeter inflection point method (WETP). In Wyoming, no one method was favored, although the R-2 Cross method was employed on a number of streams for the City of Cheyenne Stage II water development project.

The most commonly employed hydrologic method, with the exception of BR streams in Colorado, was the Tennant method. In Colorado, a hydrologic-based habitat method, using different percentiles of a flow duration curve (Hoppe method; Wesche and Rechard 1980), was applied to several streams in the Fryingpan-Arkansas Collection System.

For many of the BR projects, more than one method was used to determine the minimum streamflows. In Colorado, biological studies were conducted in conjunction with instream flow methodologies. In Montana, some of the minimum flows for older BR projects were originally determined using other methods. In recent years the MDFWP has employed instream flow methodologies, biological-habitat studies, and test flow studies to renegotiate minimum streamflows. In Wyoming, over half of the BR minimum flows were determined from the observation and measurement of test flows in addition to application of more specific instream flow techniques.

Table 7 summarizes information on the methods used to determine minimum flows with respect to the amount of the minimum flow or relative stream size. There was not a distinct pattern between particular methods used and relative stream size. However, a good proportion of streamflows within the two smallest flow categories were determined using other and undetermined methods.

4.1.2 Type of Minimum Flow Release

We identified the following three categories of minimum streamflow releases and all the minimum streamflows were classified according to one of these categories (Table 8):

(1) a single year-round minimum streamflow amount,
(2) a single seasonal minimum streamflow amount, and
(3) a flow regime (minimum streamflow amounts varying on a seasonal or annual water year basis).

Three additional attributes of minimum streamflow agreements were noted if present:

(1) series of target streamflow releases,
(2) flows to maintain a stream reach, and
(3) a maximum streamflow amount.

Two of these categories require further explanation. A flow regime indicated that there was an attempt to mimic the natural hydrograph, or that the required flows reflected fish habitat requirements during different times of the year. This category included streams with a seasonal flushing flow or

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Table 7. Methods used to determine minimum streamflow releases with respect to relative stream size, as indicated by amount of the minimum streamflow. Number of streams within each stream size category is presented with the proportion of streams in parentheses.

Method	Relative stream size (cfs)					
	0-10	11-50	51-200	201-500	501-1000	1001-4100
Biological or habitat studies	38(44)	7(30)	12(80)	3(33)		3(43)
Observation of test flow levels		1(4)	2(13)	4(55)		3(43)
IFIM	2(3)		1(7)			
Hydrologic based	15(23)	5(22)	2(13)	3(33)		
Hydraulic based	30(47)	6(26)	8(53)	5(56)		5(71)
All other methods	25(39)	10(43)	4(27)		1(100)	2(29)
Methods undetermined	3(5)	1(4)				
Total streams	64(100)	23(100)	16(100)	8(100)	1(100)	7(100)

Table 8. Type of minimum streamflow release with respect to State and agency. Number of streams in each category is presented.

	Colorado						Montana					Wyoming						
Type of release	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Basic form:																		
Year round	4	11	1	1	3		6	1	3		3	3	1		7			44
Seasonal	15				3					1		4				1		24
Flow regime	11	7			2	6			2		1	1		1	19		2	52
Additional attributes:																		
Series of target flows	1						2	1			1	2						7
Maximum flow restrictions		2					3			1				9				14
Flows to maintain a stream reach					3	6	1				4	2					1	17

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

channel maintenance flow requirement. The minimum flow agreement for a few streams included a series of two or three target flow levels. The lowest of the flows represented an absolute or critical minimum flow, while the higher flows represented desirable or optimum levels to be maintained whenever possible. Last, while the majority of minimum streamflows were intended as releases to be made at a specific location and did not guarantee the flows beyond that point, some of the minimum flows were provided to maintain streamflows throughout a specific stream reach.

The number of minimum flow types for the BR in Wyoming was greater than the actual number of stream locations (Table 8). For one of the BR streams (Shoshone River below Buffalo Bill Dam) the minimum flow release was renegotiated and changed from a seasonal flow to a flow regime. In this case, both types of minimum flow releases were considered.

A greater proportion of streams in Wyoming and Colorado (61 and 41 percent, respectively) had specified flow regimes than did streams in Montana (18 percent). Otherwise there was no apparent relationship between the type of flow release and the State or agency. All streams considered, 37 percent had a single year-round minimum release, 20 percent had a single seasonal minimum flow release, and 43 percent had a flow regime.

Four out of seven streams with a series of target flows were located in Montana, and all four were BR streams. Nine out of the 14 streams with maximum flow restrictions were FS streams in Wyoming. Seventeen of the 119 stream locations had minimum flow releases designed to maintain flows in a particular stream reach, and nine of these were minimum streamflows negotiated by the CDWR (3 are listed under the FS because the flows, while negotiated by the CDWR, were incorporated into a FS permit).

All streams within a particular category were evaluated according to relative stream size, primary use of project water, methods used to determine the minimum flow release, and the objective of the minimum flow release (i.e., resources addressed) (Table 9). There were no consistent trends among types of minimum flow releases and relative stream size or primary use of project water. A higher proportion (57 percent) of the minimum flows for streams with a single year-round release was determined using other or undetermined methods than in either of the other two categories. Use of instream flow methodologies (IFIM, hydrologic and hydraulic techniques) to determine minimum streamflows was greater in the seasonal category (0, 54, and 46 percent) and flow regime category (6, 13, and 62 percent) than in the year round category (0, 11, and 23 percent). There was no apparent relationship between the objectives and year-round or seasonal flow categories. The flow regime category, however, had a greater proportion of minimum flows that addressed more specific resources and channel maintenance.

4.1.3 Resources Addressed by the Minimum Streamflows

None of the minimum streamflow agreements we identified stated quantified goals or objectives. Language of the various permits, licenses, and other agreements was usually general, rather than specific for one or more species. Most agreements used statements such as "to maintain favorable conditions of waterflows," or "streamflows for fishery purposes," or "to protect: aquatic resources; fishery resources; trout habitat; fish and wildlife resources."

Table 9. Form of minimum streamflow release with respect to stream size, primary use of project water, methods used, and objective of the streamflow release. Amount of the minimum streamflow in cubic feet per second (cfs) was used as a relative measure of stream size. Percentages of streams in each category are presented. Number of streams is in parentheses.

Characteristic	Form of minimum streamflow release Year round (44)	Seasonal (24)	Flow regime (52)
Amount of minimum flow (cfs):			
0- 10	39	71	58
11- 50	18	21	19
51- 200	14	-	17
201- 500	11	8	6
501-1000	2	-	-
1001-4100	16	-	-
Primary use of project water:			
Irrigation	36	33	31
Power production	34	17	19
Industrial	5	-	2
Municipal	20	-	60
Flood control	7	-	-
Recreation	2	13	8
Multiple use	11	50	6
Methods used to determine minimum flow:			
Biological or habitat studies	18	50	63
Observation of test flows	18	4	2
IFIM	-	-	6
Hydrologic	11	54	13
Hydraulic	23	46	62
All other methods	50	29	23
Methods undetermined	7	-	2
Objectives:			
General aquatic habitat or fishery maintenance	70	96	63
Specific for one or more biological species	30	4	37
Channel maintenance	16	4	37

Many of the agreements did not make mention of any resource. Thus, it was difficult to determine specific goals or objectives. Given the uncertainty in determining specific resources, we analyzed the data according to three general categories:

(1) minimum streamflows that addressed aquatic resources or sport fisheries,
(2) minimum streamflows that addressed species, and
(3) streamflows that addressed channel maintenance.

The number of streams with minimum streamflow agreements that addressed each of the three resource categories is summarized by State and agency in Table 10. Seventy-three percent of all streams had agreements that addressed aquatic resources or the fishery in general, while 27 percent addressed one or more particular species. Of the latter group, only one flow addressed a specific wildlife resource. Minimum streamflows below Grayrocks Reservoir, Wyoming, while concerned with aquatic resources, also addressed waterfowl and whooping crane habitat farther downstream on the Platte River in Nebraska.

There was no distinct pattern between resources addressed and agency, except with respect to channel maintenance. Channel maintenance included seasonal flushing flows and maximum flow restrictions. Forest Service permits addressed channel maintenance more than any other type of agreement. Sixty-nine percent of the streams subject to FS permits included channel maintenance flows compared to five percent of all other agreements combined.

4.1.4. U.S. Fish and Wildlife Service Involvement in Determination of Minimum Streamflows

Consultation with the FWS in the determination of minimum streamflows was evaluated on a project basis. In Wyoming, there was only one project where it was known that the FWS was not involved in the consultation. This was a State-sponsored project (Boulder Lake) that evidently did not require Federal permits or licenses. In Colorado, the CDWR has recently entered into agreements with four ski resorts concerning diversion of water for snow-making purposes. The FWS reviewed a COE 404 application by Keystone-Arapaho Limited Partnership but recommendations concerning streamflows were not offered. One project (Crested Butte, East River) was issued a FS permit that incorporated the agreement between the State of Colorado and the ski resort. We were not able to confirm that the FWS was consulted on this or the remaining two projects.

In Montana, the MDFWP has negotiated four minimum flow agreements with the BR, as well as some of the major hydropower developers on the Missouri and Columbia Rivers. For example, Canyon Ferry, a BR dam on the Missouri, was originally constructed around 1953, and at that time the FWS evaluated the proposed project, but did not recommend a minimum streamflow. Holter Dam, located just downstream from Canyon Ferry, was constructed in the early 1900's and has in the past been subject to Federal review for a FERC license. Even though minimum streamflows were recommended by the FWS at the time of FERC licensing, the recommendations were not accepted. In the early 1980's, MDFWP initiated the Missouri River Advisory Committee, consisting of representatives from MDFWP, BR, Montana Power Company, and other water users, and they

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Table 10. Three general resource categories addressed by the minimum streamflow agreements according to State and agency. Number of streams in each category is presented.

	Colorado						Montana					Wyoming					
	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE
Number of streams	30	18	1	1	8	6	6	1	5	1	4	7	1	1	26	1	2
Minimum streamflows that addressed:																	
Aquatic resources or the fishery	24	17		1	8	3	1	1	5	1	2	6	1		15	1	1
One or more particular biological species	6	1	1			3	5				2	1		1	11		1
Channel maintenance		2				1				1					24		

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

negotiated minimum streamflow releases. The FWS did not participate in these negotiations.

For three BR projects in Montana (Tiber, Clark Canyon, and Yellowtail Dams), minimum streamflows were recommended by the FWS and are still specified in the BR's operating procedures. For all three projects the MDFWP has renegotiated flow releases with the BR. These flows are not part of formal agreements, but the BR is cooperating with MDFWP to release these flows whenever possible. Again, the FWS was not involved in these renegotiations.

Approximately 44, 44, and 35 percent of the projects in Colorado, Montana, and Wyoming, respectively, accepted the original minimum streamflow recommendations made by the FWS without modification. We did not attempt to look at factors affecting full acceptance versus modification of streamflow recommendations. A detailed evaluation of acceptance, rejection, and modification of streamflow recommendations made by the FWS is in Nelson et al. (1976). Details concerning the minimum streamflow recommendations made by the FWS and the State fish and wildlife agencies are summarized for each project in Appendix A (separate volume).

4.1.5 Availability of Daily Streamflow Data

Not all streams with minimum flow requirements had daily streamflow records that we could evaluate. The number of streams with and without streamflow data, by State and agency, is presented in Table 11. The proportion of BR streams with streamflow data was greater than for any other agency. Generally, few of the streams subject to FS special use permits had available streamflow data; however, there were some special circumstances. Fourteen of the 24 streams in Wyoming had diversion structures that were specially designed to bypass the minimum streamflow requirements before water is diverted, thus alleviating the need to install streamflow gages. One BR stream below a small diversion structure did not have a gage, but the structure was set to bypass the minimum flow at all times.

We also evaluated the availability of streamflow data with respect to relative stream size (Table 12). Overall, as stream size increased a higher proportion of streams had streamflow data. Despite this trend, almost all the BR streams had flow data regardless of stream size.

4.2 PROJECT STREAMS WITH DAILY STREAMFLOW DATA

This section presents results for those streams that had daily streamflow data. We excluded one stream in Colorado (North Fork of the South Platte River at the east portal of the Harold D. Roberts Tunnel) from this section even though data were available. The minimum flow requirement was stipulated in a BLM permit and addressed the transport and release of water via the tunnel, but the Denver Water Board has not used the tunnel in many years; the minimum flow has therefore not been maintained. Thus, 61 stream locations with flow data were evaluated (Table 13). Only seven of the 61 locations did not have minimum stream flow discrepancies.

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Table 11. Number of stream locations with minimum streamflow agreements that do and do not have available mean daily streamflow data.

	Colorado						Montana					Wyoming						
Stream locations	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Without streamflow data	3	9	1	1	8	5	0	0	4	0	1	0	0	1	24	0	0	57
With streamflow data	27	9	0	0	0	1	6	1	1	1	3	7	1	0	2	1	2	62
Total	30	18	1	1	8	6	6	1	5	1	4	7	1	1	26	1	2	119

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

Table 12. Number of streams involving each agency by relative stream size. Numbers of streams with daily streamflow data that were evaluated for minimum flow discrepancies are in parentheses. Amount of the minimum streamflow release (in cfs) was used as a relative measure of stream size.

Amount of minimum streamflow (cfs)	Agency[a]							
	BR	BLM	COE	FERC	FS	SCS	STATE	TOTAL
0- 10	16	13	0	2	30	1	2	64
	(15)	(5)		(0)	(0)	(1)	(1)	(22)
11- 50	8	3	1	3	5	0	3	23
	(6)	(3)	(0)	(0)	(3)		(1)	(13)
51- 200	8	3	1	0	0	0	3	15
	(8)	(1)	(0)				(1)	(10)
201- 500	8	0	0	0	0	0	1	9
	(8)						(9)	(8)
501-1000	0	0	0	0	0	0	1	1
							(1)	(1)
1001-4100	3	0	1	1	0	0	2	7
	(3)		(1)	(1)			(2)	(7)
Total number of streams	43	19	3	6	35	1	12	119
	(40)	(9)	(1)	(1)	(3)	(1)	(6)	(61)

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

Table 13. Number of streams that had minimum streamflow discrepancies evaluated by State and agency.

Streams	Colorado						Montana					Wyoming						
	BR[a]	BLM	COE	FERC	FS	STATE	BR	COE	FERC	FS	STATE	BR	BLM	COE	FS	SCS	STATE	TOTAL
Number with minimum streamflow discrepancies	26	8	-	-	-	0	5	1	0	0	2	7	0	-	1	1	2	55
Number of streams without minimum streamflow discrepancies	1	0	-	-	-	0	1	0	1	1	1	0	1	-	1	0	0	7
Number with daily streamflow data	27	8	0	0	0	1	6	1	1	1	3	7	1	0	2	1	2	61

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

4.2.1 Annual Trends in Minimum Streamflow Discrepancies

We divided the streams according to major river basins and evaluated the percent of streamflow records showing minimum flow discrepancies by month and by year. We looked for trends between the frequency of minimum flow discrepancies and monthly drought indices using the Palmer Hydrological Drought Atlas (Karl and Knight 1985). Within a particular river basin we could not distinguish consistent patterns between flow discrepancies and drought periods.

4.2.2 Seasonal Trends in Minimum Streamflow Discrepancies

Frequency and magnitude of minimum streamflow discrepancies were evaluated by month to see if seasonal trends existed. Initially, we divided the streams by major river basins to look for seasonal trends on a regional scale (Table 14). Generally, there was a decrease in the frequency of minimum streamflow discrepancies in June and July, whereas the winter months (December through April) had the highest frequency of discrepancies. The Lower Missouri and Colorado river basins, while generally following this pattern, had relatively high frequencies of discrepancies year round, with a slight decrease in June. The two streams in the Mississippi River basin had the highest frequency of minimum streamflow discrepancies, with a definite increase December through March and a pronounced decrease in June and July.

We also considered how relative stream size (represented by the amount of the minimum streamflow release) might affect the frequency of minimum streamflow discrepancies (Table 15). Trends were similar for all magnitudes of streamflow discrepancies; thus we present information only for discrepancies greater than 10 percent. With a few exceptions, there was a general decrease in the frequency of discrepancies in June, July, or August and an increase in frequency during the winter months. This pattern was more consistent for smaller streamflow than larger streamflow categories. Frequency of flow discrepancies in Montana was low compared with Colorado and Wyoming; thus seasonal trends were more difficult to distinguish.

Finally, we considered the effect of three major uses of water on the seasonality of minimum streamflow discrepancies: irrigation, hydropower, and municipal (Table 16). For this comparison we considered a subset of the streams for which project water was used for one of the above three purposes; multipurpose projects were not included. In streams where water was diverted or stored for irrigation or power production, the greatest number of discrepancies occurred during late fall and winter, whereas the summer months had the lowest frequency of discrepancies. For streams that were used to supply municipal water, the winter months had the highest frequency of discrepancies, but there was not a clear decrease in discrepancies during the summer. Overall, frequency of minimum streamflow discrepancies was highest for streams supplying irrigation water and lowest for streams involved in hydropower generation.

4.2.3 Effect of State and Agency on Maintenance of Minimum Streamflows

Minimum streamflow discrepancies were evaluated according to the State and the agency with which there was a minimum streamflow agreement. We summarized the results in three ways. Initially, we considered the number of

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Table 14. Frequency of minimum streamflow discrepancies with respect to month, major river basin, and magnitude of the minimum flow discrepancy. The number of locations within a particular river basin is in parentheses. Percent of daily streamflow records with flows below the accepted minimum flow amount are presented.

Magnitude of discrepancies and river basin	Frequency of minimum streamflow discrepancies by month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Discrepancies												
Columbia (4)	0.1	0.0	0.6	0.3	1.0	0.5	0.3	0.1	0.7	0.5	0.2	0.4
Upper Missouri (11)	5.1	6.2	6.7	7.2	6.2	7.1	8.4	7.1	1.6	0.4	0.1	0.3
Lower Missouri (6)	25.3	16.7	32.1	36.3	38.0	35.9	23.0	26.2	14.4	17.0	24.7	19.6
Green River (3)	0.2	3.2	8.6	15.5	14.6	12.8	17.1	4.8	0.0	0.0	0.4	1.8
Colorado (25)	17.1	16.6	19.5	20.5	23.0	21.3	25.0	13.6	9.1	14.3	19.8	24.8
Mississippi (2)	25.8	28.9	34.3	33.1	31.7	29.7	23.9	11.9	2.7	4.8	15.2	29.1
Discrepancies >10%												
Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Missouri	4.2	5.2	5.8	6.3	5.8	6.0	8.1	6.6	1.4	0.1	0.1	0.3
Lower Missouri	21.4	14.3	30.3	35.6	36.7	34.2	19.6	21.4	11.46	12.3	19.1	13.6
Green River	0.2	1.9	8.1	11.5	11.5	5.8	14.2	2.9	0.0	0.0	0.4	1.7
Colorado	8.6	6.6	7.5	7.6	9.2	7.3	15.1	9.0	5.8	9.5	13.7	17.6
Mississippi	25.7	28.5	34.1	29.6	28.8	29.0	21.7	4.4	0.5	0.1	6.8	24.5
Discrepancies >50%												
Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Missouri	1.7	1.6	2.2	2.9	3.6	3.2	4.1	6.2	0.8	0.0	0.1	0.1
Lower Missouri	5.2	5.2	8.3	17.0	18.5	11.5	3.3	5.0	1.2	0.6	2.2	2.2
Green River	0.0	0.2	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.2
Colorado	1.4	0.5	0.5	1.1	0.4	0.7	6.3	1.0	0.5	1.2	2.8	3.6
Mississippi	15.6	18.9	20.3	19.6	21.2	17.1	14.3	1.4	0.0	0.0	1.7	17.9

Table 15. Frequency of minimum streamflow discrepancies greater than 10 percent by month, stream size, and State. The amount of the minimum streamflow release in cubic feet per second (cfs) was used as a measure of stream size. Percentages of flow records with streamflows below the accepted minimum flow by more than 10 percent are presented. The number of streams is in parentheses.

Amount of minimum streamflow (cfs) and State	Frequency of minimum streamflow discrepancies greater than 10 percent by month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0- 10												
Colorado (17)	8.0	6.9	6.1	9.3	10.8	9.7	19.2	7.8	4.2	10.7	15.9	17.8
Wyoming (5)	15.3	21.3	27.9	31.7	27.6	24.3	22.5	3.6	0.0	0.0	0.6	3.1
11- 50												
Colorado (9)	9.3	11.3	12.2	12.9	11.1	9.9	15.3	6.4	1.7	1.4	4.5	8.6
Montana (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wyoming (3)	46.0	56.5	63.9	67.2	67.5	63.6	74.8	65.4	9.4	1.1	1.2	1.8
51- 200												
Colorado (8)	26.3	15.0	30.3	30.5	35.2	30.2	20.4	24.5	16.0	20.6	30.5	34.3
Montana (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
201- 500												
Colorado (2)	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Montana (1)	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wyoming (5)	0.1	0.1	1.8	1.6	1.2	0.1	0.1	0.7	0.7	0.1	0.0	0.3
1001-4100												
Montana (7)	0.6	1.1	0.6	1.3	0.6	1.0	1.0	0.4	0.1	0.1	0.0	0.1

Table 16. Frequency of minimum streamflow discrepancies greater than 10 percent by month and primary use of project water. Number of streams is in parentheses. Percentages of flow records with streamflows below the accepted minimum flow by more than 10 percent are presented.

Primary use of project water	Frequency of minimum streamflow discrepancies greater than 10 percent by month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Irrigation (14)	15.5	14.4	16.8	15.9	16.4	13.5	12.4	14.5	7.9	8.2	10.5	14.7
Hydropower (13)	1.3	1.7	1.4	1.7	1.4	2.0	0.9	0.7	0.8	0.4	0.2	0.3
Municipal (8)	4.0	3.5	5.0	9.4	11.3	9.6	3.9	3.5	3.5	6.5	6.8	6.2

streams with minimum flow discrepancies (Table 17). Of the 61 streams that were evaluated, only seven did not have minimum streamflow discrepancies. No single agency had a greater or lesser proportion of streams with minimum streamflow discrepancies. A relatively high proportion of all streams with discrepancies also had flows that were below the minimum by more than 50 percent (37 of 54 streams, or 69 percent). Over half of the streams with discrepancies had flows that were below the minimum by more than 75 percent. On a State basis, Montana had the lowest proportion of streams with minimum flow discrepancies greater than 50 and 75 percent.

Second, we considered the magnitude of minimum streamflow discrepancies by evaluating cumulative frequencies (Table 18). Across all States and agencies, 68 percent of the streamflow discrepancies were greater than 10 percent. In other words, 32 percent of the discrepancies were below the minimum streamflow amount by no more than 10 percent. At the other extreme, six percent of all the minimum flow discrepancies were greater than 75 percent. However, when streams were considered by State, the percent of all discrepancies greater than 50 and 75 percent was much lower for streams in Montana. The magnitude of minimum streamflow discrepancies was highest in Wyoming, but this was largely the result of two individual streams (FS permit for South Piney Creek below Willow Park Reservoir and an SCS project on the North Fork Powder River below Dullknife Reservoir). The pattern was consistent across States and agencies, and the percent of minimum streamflow discrepancies that were below the minimum flow amount by more than 50 and 75 percent was relatively low.

Last, information on the frequency of minimum streamflow discrepancies is summarized in Table 19. The frequency of minimum streamflow discrepancies in Montana was much lower than in Colorado or Wyoming. Less than one percent of the daily streamflow records for streams under any one agency in Montana had discrepancies below the minimum amount by more than 10 percent. Minimum streamflow discrepancies in Colorado were 29.1, 8.8, and 11.6 percent for BR, BLM, and State categories, respectively. Although the frequency of discrepancies was quite high in Wyoming, it was largely due to two streams; below Willow Park Reservoir with minimum streamflow discrepancies 38.3 percent of the time, and below Dullknife Reservoir with discrepancies 25.5 percent of the time.

Bureau of Reclamation streams in Colorado had a higher frequency of minimum flow discrepancies, of all magnitudes, than BR streams in Montana or Wyoming. In Colorado, 19 percent of all daily streamflow records showed discrepancies greater than 10 percent, and 5 percent of the records showed discrepancies greater than 50 percent in Colorado. In Wyoming only about 2 percent of the daily streamflow values were less than the minimum flow amount by more than 10 percent; mean daily flows below the minimum amount by more than 50 percent were even more uncommon. In Montana, less than one percent of the streamflow records for BR streams were below the minimum streamflow amount.

No one agency had a consistently higher proportion of streams with minimum flow discrepancies or a consistently higher magnitude or frequency of discrepancies. The most notable trend was on a State basis, where Montana had the lowest proportion of streams with minimum flow discrepancies at all magnitudes. Montana streams also had the lowest proportion of discrepancies

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Table 17. Number of streams with minimum streamflow discrepancies and discrepancies greater than 10, 25, 50, and 75 percent by State and agency.

Magnitude of minimum streamflow discrepancies	Colorado			Montana					Wyoming					TOTAL
	BR[a]	BLM	STATE	BR	COE	FERC	FS	STATE	BR	BLM	FS	SCS	STATE	
Magnitude of minimum streamflow discrepancies:														
All discrepancies	26	8	1	5	1	0	0	2	7	0	1	1	2	54
Discrepancies > 10%	23	8	1	3	0	0	0	2	7	0	1	1	2	48
Discrepancies > 25%	22	7	1	2	0	0	0	1	7	0	1	1	2	44
Discrepancies > 50%	21	6	0	2	0	0	0	0	4	0	1	1	2	37
Discrepancies > 75%	18	3	0	1	0	0	0	0	2	0	1	1	2	28
Number of Streams	27	8	1	6	1	1	1	3	7	1	2	1	2	61

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

Table 18. Within each agency category, by State, the percentage of all minimum streamflow discrepancies that were below the accepted minimum flow by more than 10, 25, 50, and 75 percent.

	Colorado			Montana					Wyoming					
Magnitude of streamflow discrepancies	BR[a]	BLM	STATE	BR	COE	FERC	FS	STATE	BR	BLM	FS	SCS	STATE	TOTAL%
Greater than 10%	66[b]	62	43	39	0	0	0	35	65	0	95	95	80	68
Greater than 25%	42	30	5	29	0	0	0	4	30	0	86	78	57	44
Greater than 50%	19	7	0	19	0	0	0	0	4	0	55	36	15	19
Greater than 75%	5	1	0	1	0	0	0	0	1	0	29	1	1	6

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

[b] Frequency of minimum streamflow discrepancies for BR streams in Colorado that were below the accepted minimum streamflow by more than 10 percent.

Table 19. Percent of mean daily streamflow records with minimum streamflow discrepancies of varying magnitude by State and agency.

Magnitude of streamflow discrepancies	Colorado			Montana					Wyoming				
	BR[a]	BLM	STATE	BR	COE	FERC	FS	STATE	BR	BLM	FS	SCS	STATE
All discrepancies	29.1	8.8	11.6	0.5	0.1	0.0	0.0	2.4	2.7	0.0	38.8	25.5	27.5
Discrepancies greater than 10%	19.1	5.5	5.2	0.2	0.0	0.0	0.0	0.9	1.8	0.0	36.9	24.1	22.6
Discrepancies greater than 25%	12.3	2.7	0.5	0.1	0.0	0.0	0.0	0.1	0.7	0.0	33.4	19.9	16.6
Discrepancies greater than 50%	5.4	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	21.5	9.1	6.1
Discrepancies greater than 75%	1.6	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	11.4	0.3	1.6

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

at magnitudes of greater than 50 and 75 percent, and the frequency of minimum flow discrepancies, at all magnitudes, was much less in Montana than any other State. Bureau of Reclamation streams in Colorado had a higher frequency of minimum streamflow discrepancies than BR streams in any other State.

4.2.4 Effect of Relative Stream Size on Maintenance of Minimum Streamflows

There was a trend observed between relative stream size (as represented by the amount of the minimum streamflow) and the frequency of minimum streamflow discrepancies (Table 20). For all agencies combined, smaller streams had higher frequencies of minimum flow discrepancies than larger streams. This trend was observed for BR, BLM, and State categories as well, but there were not enough streams of differing size to evaluate the remaining agency categories. Even though there was a trend, the streams in the two largest flow categories were all located in Montana (refer back to Table 13).

4.2.5 Frequency and Magnitude of Minimum Streamflow Discrepancies

Project streams were evaluated by State, agency, and relative size for trends in minimum streamflow discrepancies. In order to detect trends, we considered all 61 streams together and looked at the frequency distributions and magnitude of minimum flow discrepancies. Of the 61 streams, seven had no minimum streamflow discrepancies at all, 10 had no discrepancies greater than 10 percent, 6 had no discrepancies greater than 25 percent, 23 had no discrepancies greater than 50 percent and 33 had no discrepancies greater than 75 percent. Regarding frequency of discrepancies, 10 streams had minimum flow discrepancies less than one percent of the time (period of streamflow records), while 11 streams had discrepancies greater than 10 percent for less than one percent of the time. No streams had discrepancies greater than 25 percent for more than 50 percent of the streamflow records.

Table 21 describes the frequency of occurrence of streamflow discrepancies among the 61 streams with streamflow data available to us. We chose two levels of magnitude to evaluate, minimum streamflow discrepancies greater than 10 percent (Table 22) and minimum streamflow discrepancies greater than 50 percent (Table 23). The frequency intervals vary between these two comparisons because as the magnitude of discrepancies increased fewer streams had higher frequencies of discrepancies. The streams within each frequency interval were characterized by such factors as agency, type of storage dam, stream size, and resources addressed.

To interpret these tables one has to look at the distribution of streams within each block and how the distribution changes as the frequency of minimum streamflow discrepancies increases. Of the streams with discrepancies greater than 10 percent (Table 22), 64 percent were located in Montana, and as the frequency of discrepancies increases the proportion of Montana streams having discrepancies decreases. The majority of streams with the highest frequency of discrepancies were BR streams in Colorado.

Ninety-one percent of the stream locations that did not have minimum flow discrepancies were below storage dams, whereas a greater proportion of stream locations that had discrepancies 10 to 30 percent and 30 to 60 percent of the time were below diversion dams in Colorado. This same group of streams also addressed general resources, whereas streams with lower frequencies of discrepancies addressed more specific resource needs.

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Table 20. Percentage of daily flow records with minimum streamflow discrepancies by agency and relative stream size. Amount of the minimum streamflow release (cfs) was used as a measure of relative stream size. Number of streams is in parentheses.

Amount of minimum streamflow (cfs)	Frequency of minimum streamflow discrepancies by agency[a]							
	BR	BLM	COE	FERC	FS	SCS	STATE	TOTAL
0- 10	21.1 (15)	11.7 (5)	-	-	-	25.5 (1)	19.5 (1)	17.4 (22)
11- 50	17.6 (6)	4.7 (3)	-	-	24.8 (3)	- -	41.1 (1)	14.9 (13)
51- 200	29.0 (8)	5.9 (1)	- -	- -	- -	-	11.6 (1)	28.0 (10)
201- 500	1.2 (8)	- -	- -	- -	- -	- -	- -	1.2 (8)
501-1000	- -	- -	- -	- -	- -	- -	3.4 (1)	3.4 (1)
1001-4100	0.9 (3)	- -	0.1 (1)	0.0 (1)	- -	- -	2.3 (2)	1.1 (7)

[a] BR=Bureau of Reclamation; BLM=Bureau of Land Management; COE=Corps of Engineers; FERC=Federal Energy Regulatory Commission; FS=U.S. Forest Service; SCS=Soil Conservation Service; STATE=State fish and wildlife agency.

Table 21. Frequency with which different magnitudes of flow discrepancies occur. For a particular discrepancy criterion, entries represent the number of stream locations in each frequency class.

Discrepancy criterion	Frequency class[a]						Total locations
	0%	1%	1-20%	21-40%	41-60%	61-80%	
Flows below the minimum	7	10	27	11	4	2	61
Flows 90% of the minimum or less	11	11	29	7	3	0	61
Flows 75% of the minimum or less	16	13	25	6	1	0	61
Flows 50% of the minimum or less	23	15	21	2	0	0	61
Flows 25% of the minimum or less	33	20	8	0	0	0	61

[a] Percentage of days in the period of hydrologic record when measured streamflows were below the stated discrepancy criterion.

Table 22. Characteristics of streams with no minimum streamflow discrepancies greater than 10 percent and streams with flow discrepancies greater than 10 percent. Streams with minimum flow discrepancies are categorized according to whether discrepancies were recorded for one to less than 10 percent, 10 to less than 30 percent, and 30 to less than 60 percent of the mean daily streamflow records. Data are presented as the percent of streams within each frequency category. The number of streams within each frequency category is in parentheses.

	Frequency of minimum streamflow discrepancies greater than 10 percent											
	No minimum streamflow greater than 10% (11)			Less than 10% of the streamflow records (28)			10 to 30% of streamflow records (16)			30 to 60% of streamflow records (6)		
Characteristics	CO	MT	WY	CO	MT	WY	CO	MT	WY	CO	MT	WY
Agency[a]:												
BR	18	28		32	11	21	75		6	66		
BLM			9	25			6					
COE		9										
FS		9	9									17
FERC		9										
SCS												17
STATE		9		4	7				13			
Type of structure:												
Diversion dam	9			29			62			50		
Storage dam	9	64	18	32	21	21	11		19	17		33
Size of minimum flow release in cubic feet per second:												
1- 10	9		9	28		4	43		13	17		17
11- 50		9	9	14			25		6	17		17
51- 200	9	18	9	11			13			32		
201- 500				7	4	17						
501-1000					4							
1001-4100		37			11							
Resource addressed:												
General aquatic or fish habitat		46	9	50	18	18	75		19	67		33
Species specific	18	18	9	11		3	6					
Type of minimum flow release:												
Year round		46	9	14	14	7	13					
Seasonal	9	9		14		4	37		6	33		17
Flow regime	9	9	9	32	3	11	33		13	29		14
Methods used:												
Biological or habitat studies	18	18	9	25	4		69		6	67		

Table 22. Continued

Observation of test flows		18			4	14	6		17	
IFIM				3						
Hydrologic based	9			14			50	6	50	
Hydraulic based		27	9	29	4	7	25		17	
All other methods	18	27	9	29	14	4	19	13		33
Primary use of project water:										
Irrigation	9	9	9	18	4	14	19	19	17	33
Power		55		14	14	14	6	6	17	
Municipal			9	29			19			
Flood control		9			4					
Recreation				4						
Multiple uses	18			14	4		56		50	

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[a] BR=Bureau of Reclamation, BLM=Bureau of Land Management, COE=Corps of Engineers, FS=U.S. Forest Service, FERC=Federal Energy Regulatory Commission, SCS=Soil Conservation Service, STATE=State fish and wildlife agency.

Table 23. Characteristics of streams with no minimum streamflow discrepancies greater than 50 percent and streams with flow discrepancies greater than 50 percent. Streams with minimum flow discrepancies are categorized according to whether discrepancies were recorded for less than five percent, five to less than 20 percent, and 20 to less than 30 percent of the mean daily streamflow records. Data are presented as the percent of streams within each frequency category. The number of streams within each frequency category is in parentheses.

	Frequency of minimum streamflow discrepancies greater than 50 percent											
	No minimum streamflow discrepancies greater than 50% (23)			Less than 5% of the streamflow record (27)			5 to 20% of the streamflow record (9)			20 to 30% of the streamflow record (2)		
characteristics	CO	MT	WY	CO	MT	WY	CO	MT	WY	CO	MT	WY
Agency^a:												
BR	17	17	14	55	7	15	78			50		
BLM	14		4	19								
COE		4										
FS		4										50
FERC		4	4									
SCS									11			
State	4	14				4			11			
Type of structure:												
Diversion dam	22			41			56			50		
Storage Dam	13	43	22	33	7	19	22		22			50
Size of minimum flow release in cubic feet per second:												
1- 10	14		4	41		11	22		11	50		
11- 50	4	4	4	18			34		11			50
51- 200	14	9		11			22					
201- 500	4		9	4		7						
501-1000		4	4									
1001-4100		26		4								
Resource addressed:												
General aquatic or fish habitat	17	35	13	67	7	19	78		22	50		50
Species specific	17	9	9	7								
Type of minimum flow release:												
Year round	4	30	9	15	7	4	11					
Seasonal	9	4		23		7	45		11	50		
Flow regime	22	9	13	37		7	22		11			50
Methods used:												
Biological or habitat studies	26	9	4	44			67		11	50		

Table 23. Continued.

Observation of test flows		13	9	4		7	11			
IFIM	4									
Hydrologic based	13			22			67	11	50	
Hydraulic based	26	17	13	30			67			
All other methods	9	22	4	30	11	11		11		50
Primary use of project water:										
Irrigation	9	4	9	26	4	19	11	22		50
Power	4	39	9	15		7	11	11		
Municipal	13		4	30						
Flood control		4			4					
Recreation	4									
Multiple uses	13		4	26	4		67		50	

[a] BR=Bureau of Reclamation, BLM=Bureau of Land Management, COE=Corps of Engineers, FS=U.S. Forest Service, FERC=Federal Energy Regulatory Commission, SCS=Soil Conservation Service, STATE=State fish and wildlife agency.

Streams with higher frequencies of streamflow discrepancies did not appear to differ from streams with lower or no discrepancies as far as the type of flow release and methods used to determine the minimum flow amount. A higher proportion of streams with 10 to 30 percent and 30 to 60 percent discrepancies were part of multiple use projects than streams in other frequency categories. In addition, a higher proportion of streams in the none and discrepancies less than 10 percent of the time categories were associated with power production.

The same patterns that were evident for streams with discrepancies below the minimum streamflow by more than 10 percent were evident for streams with flow discrepancies greater than 50 percent (Table 23).

4.3 PROJECTS WITH UPSTREAM AND DOWNSTREAM DAILY STREAMFLOW DATA

We evaluated daily streamflow data upstream of six storage projects to determine how often the inflow was greater or less than the minimum streamflow requirement during periods when there were minimum streamflow discrepancies. We compared the percent of time there were minimum streamflow discrepancies with adjusted values that reflected only the amount of time flow discrepancies occurred and the inflow to the project was sufficient to release the required minimum flow (Table 24). For all projects, except Willow Creek Reservoir and Bighorn Lake, the adjusted values were at least 50 percent less. For Estes Lake the difference was as great as 80 percent. Thus, insufficient inflow was a major cause of discrepancies for these projects.

There was only a short period of upstream daily flow records for Willow Creek (1954-1960). It is possible that a longer period of record might reflect a trend similar to that for the above projects. Releases from Bighorn Lake were occasionally below the minimum flow and insufficient inflows correlated with approximately 26 percent of those occasions.

4.4 PROJECTS WITH TARGET FLOW LEVELS

Instead of specified minimum streamflow releases, some projects had a series of target streamflow releases. Information on projects with target flows and how often the flows were maintained is summarized in Table 25.

Target flow releases were the result of several types of negotiation. Clark Canyon, Tiber, and Bighorn Lake projects had official minimum streamflow releases of 25, 100, and 1,000 cfs, respectively. These have been the minimum releases since the projects were constructed. In later years, after the MDFWP was able to conduct aquatic studies, minimum flow releases were renegotiated with the BR, and these are the additional flows listed in Table 25. The original minimum flows are still considered the official releases; the higher releases are unofficial releases to be met as often as possible. The official releases downstream from Boysen and Fontenelle Dams were 250 and 300 cfs. The higher releases were recognized at the same time as being more desirable fishery flows, and the BR unofficially agreed to release these amounts whenever possible. The three flow releases for McPhee Dam were formally incorporated into the BR operating procedures and represent the minimum flow release in a dry, normal, and wet year.

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Table 24. Percent of streamflow records showing minimum streamflow discrepancies when inflow to the project was not considered and when the inflow to the project was sufficient to release the minimum streamflow amount. Frequency of minimum flow discrepancies is given for all discrepancies and discrepancies greater than 10, 25, 50, and 75 percent.

Project and period of streamflow record	Percent of streamflow records showing minimum streamflow discrepancies of:					Percent of streamflow records, when inflow was sufficient to release the minimum flow, showing minimum streamflow discrepancies of:				
	Total	> 10%	> 25%	> 50%	>75%	Total	>10%	> 25%	> 50%	> 75%
North Fork Powder River below Dullknife Reservoir, Wyoming (1975-1985)	43.8	41.5	34.3	15.7	0.6	20.1	18.3	16.5	3.9	0.0
Blue River below Dillon Reservoir, Colorado (1967-1986)	6.0	3.8	2.5	2.2	0.3	2.6	1.6	0.8	0.6	0.1
Lake Creek below Twin Lakes Reservoir, Colorado (1979-1985)	13.9	13.2	11.4	4.0	0.3	3.8	3.6	2.9	0.9	0.1
Big Thompson River below Lake Estes, Colorado (1950-1985)	64.5	57.4	40.0	17.1	4.2	14.8	11.1	3.0	1.4	0.6
Willow Creek below Willow Creek Reservoir, Colorado (1954-1960)	33.9	8.1	0.8	0.0	0.0	33.6	8.0	0.7	0.0	0.0
Bighorn River below Bighorn Lake (Yellowtail Dam), Montana (1967-1987)	1.1	0.9	0.7	0.5	0.0	0.8	0.8	0.6	0.4	0.0

Table 25. Percent of daily flow records where target streamflow releases were maintained for water development projects with a series of target streamflow releases.

Project	Target streamflow release (cubic feet per second)	Period of record	Percent of time the target streamflows were maintained
McPhee, Colorado	20	(1985-1987)	100
	50	(1985-1987)	98
	78	(1985-1987)	65
Yellowtail, Montana	1000	(1967-1987)	98
	1500	(1986-1987)	99
	2000	(1986-1987)	97
	2500	(1986-1987)	82
Canyon Ferry, Montana	2400	(1985-1987)	99
	3000	(1985-1987)	92
	4100	(1985-1987)	67
Clark Canyon, Montana	25	(1965-1987)	100
	200	(1976-1987)	75
Holter, Montana	2400	(1985-1987)	100
	3000	(1985-1987)	100
	4100	(1985-1987)	81
Libby, Montana	2000	(1972-1986)	99
	3000	(1972-1986)	92
	4000	(1972-1986)	75
Tiber, Montana	100	(1956-1987)	99
	250	(1977-1987)	81
Boysen, Wyoming	100	(1952-1967)	99
	250	(1968-1987)	99
	400	(1968-1987)	97
Fontenelle, Wyoming	300	(1964-1985)	98
	500	(1964-1985)	89

The releases downstream from Canyon Ferry and Holter Dams have already been mentioned. These releases resulted from negotiations between MDFWP, BR, and Montana Power Company and have never been incorporated into a signed document.

Maintenance of the minimum streamflow release was above 98 percent for all projects. Three projects, Holter, Clark Canyon, and McPhee, never had streamflow releases below the minimum amount. Maintenance of the higher target flows was above 80 percent for most of the projects. The highest target flow generally corresponded to a release that could be afforded only in above average runoff years; thus maintenance of these higher flows was understandably less frequent.

5. DISCUSSION

5.1 CHARACTERISTICS OF WATER DEVELOPMENT PROJECTS WITH MINIMUM STREAMFLOW AGREEMENTS

5.1.1 Differences Among States

The proportion of stream locations with minimum streamflow requirements among States appears to reflect regional differences in water development activity, consumptive demands, and hydrology. According to a 1984 USGS map of water resource development projects (U.S. Geological Survey 1984), Colorado has three times more existing development projects in Wyoming and more than two times the number in Montana. Sixty-four of the 119 stream locations with minimum flows that we identified were located in Colorado (Table 2). The Denver metropolitan area has created high water demands for municipal, power, and industrial purposes. The situation is confounded by complex transmountain diversions from the less populated Colorado River basin on the western slope of the Rocky Mountains. The demand for available water (Figures 4 through 6) is greater in Colorado than in Montana or Wyoming.

The proportion of streams with minimum flows in Wyoming versus Montana appears to reflect regional hydrology (Figures 5 and 6). The need to secure a dependable source of water during the summer months, especially for irrigation, is greater in Wyoming than in most of Montana, where average annual runoff and discharge rates are higher. Many of the Wyoming projects we identified involved small reservoirs on streams that have low and intermittent flows during the late summer and winter months. With development of these streams, agencies have had to confront conflicts between consumptive and nonconsumptive uses more often than would occur in a region with naturally higher flows.

Other factors, such as differences in State politics, instream flow legislation, and recognition of instream flow needs, also affect the number of projects having streamflow agreements. These factors may have a greater impact on more recent water developments and developments currently being reviewed or constructed than on older projects. Seventy-two percent of the streams with flow agreements that we evaluated existed prior to any State instream flow legislation. Even so, regional hydrology and existing conflicts between water uses cannot be ignored. For example, recognition of instream flows issues in Colorado and Montana is relatively high, and State instream flow legislation was passed in 1973 and 1969, respectively, yet the nature of existing conflicts differs. The differences can be partly ascribed to regional hydrology (i.e., there is more available water to work with in Montana) and consumptive demands. These conflicts in turn contribute to the political environment.

5.1.2 Differences Among Agencies

The authority of the FWS to review proposed water development projects and make recommendations concerning maintenance of streamflows for fish and wildlife resources was established by the Fish and Wildlife Coordination Act (FWCA). The FWCA, originally passed in 1934 and subsequently amended in 1946 and 1958, requires consultation with the FWS and appropriate State fish and wildlife agencies prior to construction of federally funded water developments or non-Federal developments requiring a Federal permit. The FWCA requires that the recommendations of the FWS be given full consideration with respect to Federal projects and gives the FWS the authority to recommend that Federal permits be denied or conditioned to reduce impacts on fish and wildlife resources (Bean 1983). The FWS generally works with State resource management agencies in conjunction with State water law to secure acceptable instream flow agreements.

The National Environmental Policy Act (NEPA) of 1969, originally proposed as an amendment to the FWCA (Bean 1983), requires all Federal agencies to prepare environmental impact statements on "proposals for legislation and other major Federal actions significantly affecting the quality of the human environment". The responsibilities of the FWS and State fish and wildlife agencies defined by the FWCA did not change with the enactment of NEPA. The value of NEPA is its broad environmental policy and the requirement for detailed studies of all Federal actions and subsequent review by fish and wildlife agencies and public interests. Thus, NEPA acts in concert with the FWCA, while requiring more detailed consideration of a broader range of environmental resources and associated impacts that the FWCA alone.

The proportion of streams with minimum flows subject to the various Federal permits and licenses reflects the responsibilities and objectives that have been established for those agencies. Two factors may influence the proportion of FS versus BLM permits with minimum flow conditions. First, a greater proportion of headwater streams in the Rocky Mountains are located on FS land than on BLM land; thus the proportion of water developments in general is greater on national forest land. Second, the Organic Act of 1897 stated that the purpose of a national forest was to "secure favorable conditions of water flows, and to furnish a continuous supply of timber..." (The Forest Service Organic Administration Act of 1897). The Act did not specifically address flows for fish and wildlife resources, but it has been interpreted for such purposes. With the enactment of the Multiple Use Sustained Yield Act of 1960, the purpose of national forests was further defined:

> "... it is the policy of Congress that the National Forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fishery purposes."

The Federal Land Policy and Management Act (FLPMA) of 1976 gives authority to the Secretary of Agriculture to manage national forest lands for multiple purposes, including fish and wildlife, and to require measures to protect such resources (e.g., stipulations for minimum streamflows in permits, easements, and right-of-ways) (Fifer 1980). The Organic Act, Multiple Use Sustained Yield Act, and FLPMA are three major pieces of legislation that apply to the national forest system, and resource managers have asserted the authorities defined in these acts to address fish and wildlife needs and condition FS special use permits.

Two of the major pieces of legislation applying to National Resources Lands (BLM lands) are the Taylor Grazing Act of 1934 and the Classification and Multiple Use Act of 1964 (Bean 1983). These are very similar in their definition of responsibilities to the Organic Act and Multiple Use Sustained Yield act, respectively. The authority for BLM to require protective measures for fish and wildlife resources is established by FLPMA (Bean 1983). Thus, it appears that similar legal avenues are available to both FS and BLM resource managers to require permits to be conditioned for fish and wildlife resources. However, based on our interviews with BLM resource managers, it appears that they view allocation of water as a State responsibility, and believe that there are no legal avenues similar to those for the FS that allow BLM to request or require minimum streamflows for fish and wildlife purposes. It is possible that, at the agency level, the FS has been more assertive because it encountered water management conflicts earlier in the history of national forests and more frequently than BLM. Interpretations of the Organic Act and Multiple Use Sustained Yield Act also have been litigated to a greater extent than similar legislation concerning BLM resource management (Bean 1983). Thus, legal avenues for BLM may not be as well known or tested.

With one exception, all BLM permits that we identified were in Colorado and appear to have been conditioned through the efforts of the FWS and CDWR acting in accordance with the Fish and Wildlife Coordination Act. However, there is some indication that BLM State resource managers are becoming more active in negotiations for minimum flows, perhaps in response to the intensity of water conflicts in Colorado.

Section 404 of the 1972 Federal Water Pollution Control Act (FWPCA) requires the COE to establish regulations and issue permits to control the discharge of dredged and fill material into waters of the United States. The responsibilities of the COE regarding permit conditioning for minimum flows remain subject to interpretation of Section 101 of the Clean Water Act (CWA). The general guideline followed by the COE, when issuing Section 404 permits, is that allocation of water in the western States is governed by State laws and is not a national responsibility (U.S. Army Corps of Engineers 1985). The reasoning is that minimum flows conditioned by 404 permits cannot be enforced because such conditions do not prevent the State from allocating any amount of the flows at a future date. However, the FWS has interpreted the intent of Congress to be that, while the State allocation system and water rights can not and should not be disregarded, Section 404 permits are not prohibited from considering the impact of water withdrawals on fish and wildlife resources. The result is that cases may have to be relatively strong in order for the COE to condition 404 permits. Permits for the White River below Taylor Draw Reservoir, Colorado, and Pine Creek below Fremont Lake, Wyoming, appear to have been conditioned in response to biological opinions from the FWS concerning the endangered fishes downstream in the Colorado River. COE 404 permits for some of the BR Fryingpan-Arkansas project streams recognized minimum flow releases because potential conflicts between public interests and water for aquatic resources had been alleviated by other agreements.

The proportion of constructed FERC projects identified in Colorado and Wyoming reflects the lower economic feasibility of small hydropower development, due to lower and more unreliable streamflows, as compared to Montana. In addition, despite the increase in small hydropower development prompted by the enactment of the Public Utility Regulatory Policies Act in 1978 (O'Connor 1985), many of the licensed projects that have minimum flow stipulations have not been constructed and were not part of our evaluation.

A large proportion of the minimum flows we identified were associated with BR projects. Developments that are part of the Colorado River Storage Project were authorized to provide water for agriculture, municipal and industrial growth, flood control, and fish and wildlife preservation (U.S. Bureau of Reclamation 1984). Thus, while the Fish and Wildlife Coordination Act requires full consideration of fish and wildlife resources and consultation with the FWS and the State, the nature of the project authorization further obligates BR to adopt measures for the protection of these resources. The majority of BR projects are large-scale developments with high public visibility, which tend to elicit greater concern and effort to insure protective measures such as minimum flow releases.

5.1.3. Differences Among Projects With Minimum Streamflow Agreements

The majority of studies determining minimum streamflow needs downstream of proposed water development projects were conducted by State fish and wildlife agencies and the FWS. Thus, the systematic methods used to assess minimum flows appear to be agency choices rather than the result of project characteristics. State agencies most frequently used the instream flow methodology employed by the State to determine water appropriations, rather than methods that are specifically designed for negotiating flow releases (e.g., IFIM). The FWS generally used methods similar to the States' since many studies were conducted cooperatively. More recently, several instream flow techniques were often applied to the same stream in order to compare estimates and field test new methodologies. For example, studies associated with Strontia Springs Diversion Dam in Colorado included use of the R-2 Cross, Tennant, and IFIM methodologies. This situation resulted from the controversy surrounding the project, the number of Federal and State agencies involved, and the fact that the developer (Denver Water Board) used several techniques in order to compare results derived by the agencies and have several flow values from which to negotiate an agreement.

The Instream Flow Incremental Methodology was rarely used to determine streamflow releases for the projects we identified. State agencies feel that this method is too time- and money-intensive, even through it may be an appropriate method for negotiating streamflow releases. In addition, the CDWR and MDFWP have been applying R2-Cross and Wetted Perimeter Inflection Point methodologies, respectively, to file for instream flow rights, so field personnel are more familiar with these techniques.

Bureau of Reclamation projects employed more methods per stream and more complex methods. Funds and manpower available for BR projects are generally greater due to the large scale of the developments and high public visibility. This contention is supported by the high proportion of smaller projects where nonsystematic methods (All Other Methods and Methods Undetermined categories, Table 7) were used to determine the minimum releases. There is a time factor involved (i.e., the instream flow methodologies were not widely used prior to 1970), but even adjusting for time there was a higher proportion of BR projects relying on biological and habitat data, or test flow observations.

There was not strong evidence to support a relationship between methods applied, resources addressed, and type of flow release. It would seem reasonable that more systematic methods would be applied when a specific resource or species was of concern. However, available funds and relative importance of the development may be more important in determining the nature of the studies conducted. Lack of a distinct pattern also may be related to the difficulty of determining the specific resources that minimum flows address.

The FS was the only agency that consistently addressed channel maintenance. Even FS permits issued in the late 1950's and early 1960's were conditioned with maximum flow restrictions to protect stream channel integrity. Examination of more recent FS permits (e.g., streamflow conditions for the City of Cheyenne Stage II Water Development Project) suggest that the FS has shifted emphasis from requiring a minimum streamflow and a maximum flow restriction to a flow regime that mimics the natural hydrograph. Thus, the more recent permits require flushing or channel maintenance flows during spring runoff. This emphasis reflects the goals of the FS to maintain "favorable conditions of water flow" (Organic Act 1897).

5.2 AVAILABILITY OF DAILY STREAMFLOW DATA

It is apparent that larger streams are more likely to have available streamflow data than smaller streams. Two factors are involved. First, the proportion of headwater streams with existing streamflow gages is less than for larger streams and rivers. This reflects the fact that there are far more headwater streams, and larger streams and rivers are subject to more use, thus requiring monitoring of flows. Second, development of smaller streams often involves local irrigation districts or other private interests for whom installation and maintenance of streamflow gages can be cost-prohibitive. The USGS has recently cut back on the number of streamflow gages it operates and maintains; thus, cooperative arrangements and cost-sharing between smaller operators and the USGS are less feasible.

A very high proportion of BR project streams, regardless of size, had streamflow gages and available data. Bureau of Reclamation projects generally have the necessary funds to install gages where none exist. We also found that BR flow records were easier to obtain than records from other developers if USGS data were not available. Private developers are not obligated to make available daily flow records from project operations. Thus, access to records for non-Federal projects without USGS data is difficult.

5.3 MAINTENANCE OF MINIMUM STREAMFLOW RELEASES

Minimum streamflow releases are designed to protect existing resources from the impacts of water development operations. The minimum flow release is a product of what the State and Federal agencies have determined to be necessary and what developers are willing and able to accept. From the perspective of protecting the resource, it is instructive to assess how often the minimum flow is maintained, rather than the extent of compliance with the language of the agreement. We make this distinction because many agreements included conditions under which the minimum flow could be reduced. For our purposes, it was more appropriate to evaluate how often the minimum flow was maintained and then to attempt to identify the factors affecting maintenance.

5.3.1 Annual and Seasonal Trends

There was no distinct pattern between drought periods and frequency of minimum streamflow discrepancies. It is possible that a relationship exists, but we were not able to detect it at the scale we used. Considering a finer scale, some individual stream locations did show an increase in discrepancies during drought periods. An extreme drought occurred in 1977, which especially affected the Colorado Rocky Mountain region (Karl and Knight 1985). During 1977, approximately 33.3 percent of the projects in the Colorado Rockies showed an increase in the number of minimum flow discrepancies, 52.3 percent showed no apparent change in the number of discrepancies compared to other years, and 14.3 percent had fewer discrepancies compared to other years. Streamflows in the Colorado River below Lake Granby were below the minimum flow release for 292 days in 1977; however, during 15 of the 35 years with streamflow records, flows were below the minimum over 200 days per year. In contrast, streamflows below Williams Fork and Dillon Reservoirs (both located on tributaries of the Colorado River) showed no minimum flow discrepancies in 1977, but for each project six percent of all the streamflow records exhibited discrepancies. Thus, it seems that while minimum flow discrepancies may increase during drought periods for some individual projects, there are other overriding factors affecting maintenance of minimum streamflows.

The shape of the annual hydrograph, associated with use of project water and regional hydrology, appears to be a major factor affecting seasonality of minimum streamflow discrepancies. Generally, discrepancies were greater during the winter and decreased during the early summer. This pattern corresponds to an annual hydrograph (i.e., streamflow pattern) that is characteristic of the Rocky Mountain region. Streamflows are at their lowest during fall and winter followed by a dramatic increase during spring runoff and a gradual decrease throughout the summer. High-flow months are least affected by water withdrawals, because the proportion of available water used is much less than during low-flow months (Montana Department of Fish and Game 1979).

Coupled with the natural hydrograph effect is the effect of water management and control. Projects that supply irrigation water release more water during the summer months, further decreasing the likelihood of minimum flow discrepancies. Single-purpose reservoirs (e.g., Dullknife Reservoir, Wyoming) stop receiving calls for water in the late summer or early fall. At this time the gates are shut down to retain storage; thus, as little water as possible is released during the natural low-flow months, which increases the likelihood of minimum flow discrepancies.

Seasonality of discrepancies was apparent within all the major river basins (Table 14), but frequencies and magnitudes were much less in the Columbia and Upper Missouri River basins. These differences can be attributed to regional hydrology (Figures 4 through 6) coupled with primary use of project water. The majority of projects in these two river basins are used for power generation (e.g., Libby, Kerr, and Canyon Ferry Dams). Maximum powerload demands occur during the winter; thus, stored water is released during the low-flow months (U.S. Army Corps of Engineers 1984), decreasing the potential for minimum flow discrepancies.

5.3.2 Trends in Minimum Streamflow Discrepancies Among States

Regional hydrology, extent of water development activity, and primary use of project water were the most evident factors correlated with differences in minimum streamflow discrepancies among States. The most consistent pattern was that Montana had proportionately fewer streams with minimum flow discrepancies and, for those streams with discrepancies, frequencies and magnitudes were less than in Colorado or Wyoming. Higher annual runoff and average discharge (Figure 5) in Montana, together with proportionately fewer water developments than Colorado (i.e., fewer conflicts between consumptive and nonconsumptive uses), decrease the likelihood that minimum streamflow discrepancies will occur in Montana.

Montana and Colorado represent opposite ends of a continuum based on extent of consumptive demands in proportion to the available water resource. Hydrologic conditions in Wyoming are more similar to patterns in Colorado (drier end of the continuum), but demands for water are not as great. The nature of consumptive demands further separates Montana and Colorado. It has been mentioned that a high proportion of projects in Montana generate hydroelectric power and that timing of water releases is different than for irrigation, municipal, and other purposes. Moreover, water control for hydropower results in storage and altered flow regimes, but water is not removed from the system, or at least the rate of loss is much less than it is for other consumptive uses. In Colorado, a higher proportion of irrigation, municipal, and multipurpose projects exists, and the situation is confounded by large-scale transmountain collection and diversion systems that remove water from the headwaters of the Colorado River system.

The differences among States do not imply that the conflicts between consumptive and nonconsumptive uses are any less important, but they help to identify why more problems with maintenance of minimum flows may exist in one State versus another. In fact, even though maintenance of flows tends to be greater in Montana, aquatic resources are being impacted by another aspect of water releases from hydropower operations: fluctuating flow levels (Interagency Instream Flow Task Force 1979). Resource managers in Montana have been focusing research efforts on this problem (Fraley and Graham 1982).

5.3.3 Effect of Project Characteristics on Maintenance of Minimum Streamflows

The methods used to determine minimum streamflow requirements did not appear to be correlated with maintenance of flows after projects were constructed. Nelson et al. (1976) stated that Rocky Mountain projects using more detailed methodologies (e.g., transect analysis, incremental analysis, gaging records) had a higher probability of the recommended flows being accepted and a higher probability of flow violations. However, they evaluated flow violations using both gaging records and subjective information. Thus, they concluded that projects using detailed methodologies usually had available streamflow data and it was easier to verify violations. To avoid these types of biases, we did not analyze subjective information regarding maintenance of flows. What is evident, both from Nelson et al. (1976) and from our analysis, is that detailed methodologies may lead to higher probability of acceptance, but higher maintenance of minimum flows does not necessarily follow.

There was some indication that frequency and magnitude of streamflow discrepancies was less for minimum flows addressing more specific resources (Tables 22 and 23). This indicates that more effort and cooperation to maintain minimum flows may exist if the goals are well defined. A confounding factor, through, is that many minimum flows that address a specific resource involve a high quality fishery (i.e., Gunnison River below Taylor Park and Crystal Dams, Missouri River below Canyon Ferry and Holter Dams). Generally, projects upstream from a quality fishery, regardless of whether the goals are specific or not, tend to be closely monitored by the State agencies, and deviations in flow levels are more visible to the public.

Frequency and magnitude of minimum flow discrepancies (Tables 22 and 23) were not less for streams releasing a single year-round or seasonal flow versus streams with varying flow requirements throughout the year. This suggests that flow regimes requiring more operational adjustments (i.e., requiring operators to reset valves or gates more frequently) do not increase the likelihood that minimum flow discrepancies will occur.

There was evidence to indicate that maintenance of minimum flows was greater downstream from storage dams versus diversion dams. The reasoning is that storage operations have the capacity to release water in excess of upstream flows in order to maintain minimum levels during low-flow periods. However, we did not identify any agreements that obligated operators to release storage when inflows were less than the minimum requirement. Most agreements specify that outflow can equal inflow when upstream flows are below the minimum requirement. Even when agreements are not framed with this exception, it is still the general interpretation, and most operators do not feel they have any obligation to augment low flows by releasing additional storage.

5.3.4 Influence of Upstream Flows on Maintenance of Minimum Streamflows

a. Projects with upstream flow data. While few projects had both upstream and downstream records, our analysis indicates that low upstream flows can account for a high proportion (over 50 percent) of minimum streamflow discrepancies. This may be a particularly important consideration for projects in Colorado and Wyoming. For only one of the Colorado projects, Willow Creek Reservoir, did upstream flows not explain a high proportion of the flow discrepancies. The BR stated that low natural flows above Lake Estes have been recognized as a problem for many years and our analysis verifies that situation.

Low-flow conditions above Dullknife Reservoir (Powder River basin, Wyoming) accounted for over 50 percent of the minimum streamflow discrepancies. Frequency and magnitude of discrepancies for Willow Park Reservoir (flow discrepancies summarized in Table 19 under FS), also located in the Powder River drainage, were very similar to those for Dullknife. It is plausible that low upstream flows to Willow Park may be related to a high proportion of the minimum flow discrepancies. Information collected from Wyoming Game and Fish Department biologists suggests that low streamflows in that region may be a primary factor.

b. Projects without upstream flow data. It was difficult to assess whether low upstream flows were a primary factor contributing to minimum flow discrepancies for projects without upstream gages. State and FWS biologists and project operators were contacted to determine primary causes of flow discrepancies. Except for a few cases, discussed below, the general response was that low upstream flows were the most important factors.

Some projects have conditions under which the minimum flow releases can be reduced by certain amounts if low flows are predicted. For example, releases from Lake Granby can be reduced by 15, 20, 25, or 30 percent based on inflow forecasts. Streamflow records below Lake Granby exhibited minimum flow discrepancies 53 percent of the time over 35 years. However, flow releases below the minimum by more than 25 percent occurred only 6 percent of the time, and flows below the minimum by more than 50 percent occurred only 1 percent of the time. Thus, it is possible that the high frequency of minimum flow discrepancies below Lake Granby is the result of reductions due to low inflow forecasts.

Releases below Grayrocks Reservoir in Wyoming can be reduced as much as 50 percent from October through March if storage drops below 50,000 acre feet. Considering this condition, approximately 77 percent of the flow discrepancies may be related to low inflows. There are additional conditions in the Grayrocks Reservoir agreement that allow the flow to be reduced in response to low inflows, but without upstream records we could not assess whether or not low inflows were related to more than 77 percent of the discrepancies.

5.3.5 Identification of Additional Factors Affecting Maintenance of Minimum Streamflows

The following discussion deals with various aspects and conditions of projects that may influence maintenance of minimum streamflows. It was impossible to collect consistent information on factors affecting maintenance due to lack of records and project monitoring. Thus, the following discussion relies heavily on professional judgment and personal recollection of State and FWS personnel and project operators. The projects discussed are presented as examples and do not represent the only projects exhibiting various conditions.

Upstream flow conditions have been discussed as a factor influencing maintenance of minimum flow requirements, but they are mentioned again due to the frequency of this response. Analyses of streamflow data suggest that low upstream flows are correlated with a high proportion of minimum flow discrepancies; thus, the subjective information may be representative.

Several Denver Water Board (DWB) projects subject to BLM permits were identified as having consistent problems due to the language of the minimum flow agreements. The major problem resulted from the number of exceptions associated with the minimum flows being released. For example, the minimum release from Dillon Reservoir can be reduced if the combined storage of Dillon and three additional reservoirs is not above the estimated annual use of water through the Denver Water Works System. There are additional exceptions regarding storage in Dillon Reservoir that allow the DWB to reduce releases if the board decides there is an insufficient water supply.

The minimum bypass flow requirements for the Fraser River Diversion Project include the following clause:

> "...bypasses will be so made, except when in the opinion of the Board (DWB) to do so would impair the operations of the water works system."

Even DWB representatives commented to us that these agreements contain considerable latitude and are difficult to interpret and monitor.

Other language that has resulted in problems includes exceptions allowing the DWB to reduce flows for emergencies, maintenance, and repairs. These types of exceptions are not unusual in minimum flow agreements, but lack of specific language to define what constitutes an emergency and the period of time that flows can be reduced has resulted in situations that are unsatisfactory to the CDWR. All of the DWB projects, while subject to BLM permits, have signed agreements with CDWR (these agreements being incorporated into the BLM permits). Evidently, the BLM does not monitor the agreements, so the responsibility appears to have been left up to the State of Colorado.

We identified one case where the agreement was initially misinterpreted but later rectified. Windy Gap Diversion Project, located on the Colorado River, has minimum releases that are designed to maintain streamflows from the diversion point downstream to the mouth of the Blue River. The conservancy district operating the project misinterpreted the agreement as requiring that the minimum flows be met at three locations rather than throughout the reach. The language of the agreement is not difficult to interpret; thus it appears there was miscommunication between project administrators and the actual operators.

Stateline and Meeks Cabin Dams, both BR projects that are operated by local conservancy districts, are examples of projects that have had problems with the minimum flows being released. The problems with minimum releases from Meeks Cabin Dam appear to have been related to the operators not being fully aware of the minimum flow requirements; thus water was regulated according to the needs of downstream irrigators. The BR assumed the conservancy district was following the agreement, but because they were not monitoring the operation, the problem went unnoticed until the WGFD notified the BR in the Colorado River Basin regional office.

Problems maintaining flows below Stateline Dam were related to lack of monitoring during the winter. Information from the BR indicates that the gates were being set to release the inflow after the last call for irrigation. Therefore, when inflow levels changed the operators were not available to readjust the gates.

Bureau of Reclamation employees stated that most of the time when flows below the minimum bypass requirement for the diversions on the Frying Pan River system occurred it was due to low upstream flows. We did not have upstream flow data to evaluate this situation; however, we did have data below seven of 12 diversions, which indicated times when water was being diverted. According to the operating principles, when natural flows are less than the minimum flows, water will not be diverted. Our analyses indicate that there were occasions when water was being diverted and the minimum streamflows were not being bypassed. Information from the FWS suggests that these situations are not intentional but reflect the lack of manpower to monitor and reset the gates of diversion structures every time there is a change in streamflow. The gates are set to release the minimum, but when stream discharge changes the amount of water bypassed also changes.

Several additional factors were identified as causing temporary reductions in minimum streamflow releases, but not causing consistent problems.

1. Mechanical shutdowns resulting from power outages and equipment failure. Most projects experience temporary flow reductions due to operational failures. For example, shutdowns (according to BR representatives operating the Colorado-Big Thompson and Frying Pan Arkansas projects) generally occur when back-up systems fail to take over after a power outage, and then it may take up to several hours to restart the system manually.

2. Reduction in minimum flow releases due to construction, repair, and maintenance work. Buffalo Bill, Fontenelle, and Gray Reef Dams, Wyoming, are examples where construction and repairs have caused temporary reductions in flow releases. Tiber Dam in Montana had initial problems with the spillway, requiring several years of repair work that resulted in minor flow reductions. Flows below Yellowtail Dam are discontinued every fall to check for seepage, but these reductions are not reflected in the average daily streamflow data because they are of such short duration. However, it is a situation that the BR and MDFWP are trying to resolve.

3. Reduction in minimum streamflow releases due to emergency situations. Crystal Dam in Colorado and Kortes and Gray Reef Dams in Wyoming have, in the past, had to reduce flows to allow rescue workers to search for drowning victims. Additionally, flows have been reduced to decrease flooding danger to downstream population centers (e.g., Gray Reef Dam, Wyoming).

Thus far, the factors identified have contributed to non-maintenance of minimum streamflow releases; however, there are cases where certain attributes of the agreements have probably increased flow maintenance. Informal agreements between MDFWP and various operators, including the BR, have a high degree of maintenance compared to the majority of projects we evaluated. Several factors influencing maintenance of releases from these Montana projects have been discussed (i.e., more available water and use of the water for hydroelectric generation decrease the likelihood of minimum streamflow discrepancies), but the cooperation between MDFWP and other water users has resulted in continued effort to maintain aquatic resources and flexibility to adjust and improve goals.

Another attribute of informal and other agreements in Montana, as well as several agreements with the BR in Colorado and Wyoming, is the target flow option. Bureau of Reclamation operators in the Upper Missouri River basin stated that they liked to receive this type of an option because it provides flexibility and promotes negotiations, contrary to the ultimatum of a single flow value. In our streamflow evaluation, projects with target flow levels had relatively high maintenance of streamflow releases (Table 25).

Despite the fact that the stated agreements appear to be working well in Montana and for some BR projects in Colorado and Wyoming, this does not suggest that this type of agreement would be satisfactory under all circumstances. From information concerning DWB projects, it is apparent that more restrictive agreements are sometimes required to protect instream benefits.

5.4 EVALUATION OF BIOLOGICAL EFFECTIVENESS

Water development projects with minimum streamflow requirements in Colorado, Montana, and Wyoming have been identified, and available streamflow data analyzed to evaluate implementation and maintenance of streamflow releases. The next step of the process is biological evaluation. Biological evaluation was not within the scope of this study, but factors influencing the selection of candidate projects for evaluation have been identified.

Water development projects with pre- and post development biological data are candidates for evaluation. However, the majority of projects identified in this study did not have pre-development data that could be used to evaluate effectiveness of minimum streamflow releases. Furthermore, older projects with data may not be appropriate to evaluate due to more recent upstream developments. Isolating ecological responses to altered flows from one project becomes very difficult with additional impacts from upstream developments, and the value of pre-project data (if it predates the upstream development) becomes questionable.

An alternative is to evaluate projects from the perspective of pre- and post-implementation of minimum streamflows. Several projects incorporated minimum streamflow releases many years after original construction (e.g., Hebgen, Ennis, and Clark Canyon dams in Montana, Taylor Park Dam in Colorado) and have biological data to evaluate the response of the downstream fishery to changes in streamflows.

Another consideration, especially for older projects, is the original objective of the minimum streamflow release. Evaluation should be in accordance with the original objective. For some of the projects it was difficult to identify the goal of the minimum flow release. Part of this situation is a result of the objectives of the various agencies involved. For example, the FS might consider channel maintenance to be the goal of a streamflow release, while the FWS and State agency may consider it to be for the maintenance of brown trout. These goals can be compatible, but lack of specification in the agreements can lead to confusion, and it is difficult to go back and identify the original intent.

Streams associated with the Fryingpan-Arkansas Collection System are possible candidates for evaluation of biological effectiveness of minimum streamflows. Diversion structures are located on headwater streams of the Fryingpan River, and biological surveys and instream flow analyses were conducted before construction. From our streamflow analyses one stream appears to have had no minimum flow discrepancies since diversions began (North Cunningham Creek), and streamflow discrepancies for other streams varied from 2 to 5 percent of the time up to more than 20 to 30 percent of the time. Thus, evaluations could be conducted to compare streams based on the history of streamflow releases. Additional candidates for evaluation of biological effectiveness of minimum streamflows are noted in Appendix A.

6. SUMMARY

Thirty-six, 14, and 23 water development projects with minimum streamflow agreements were identified in Colorado, Montana, and Wyoming, involving minimum streamflow releases for 64, 17, and 38 stream locations, respectively. Differences in the number of streams with minimum flow releases among States appeared to be related to differences in regional hydrology, extent of water development activity, and nature of consumptive demands.

Proportion of streams subject to various Federal permits and licenses generally corresponded to the mandates of those agencies. The FS seemed to be more assertive in its efforts to directly require minimum streamflow stipulations in special use permits than did BLM, COE, or FERC. Bureau of Reclamation projects, under the FWCA, have to give full consideration to recommendations from the FWS and the State fish and wildlife agency. Authorizing legislation for BR projects also often requires fish and wildlife considerations.

Sixty-one streams with minimum streamflow agreements also had available streamflow data and were evaluated to determine how often the minimum streamflow releases were maintained. There were no distinct patterns in minimum streamflow discrepancies among agencies. The most consistent pattern was that Montana had proportionately fewer streams with minimum streamflow discrepancies, and for those streams with discrepancies, frequencies and magnitudes were less than in Colorado or Wyoming. Bureau of Reclamation streams in Colorado had higher frequencies of minimum flow discrepancies, of all magnitudes, than BR streams in any other State. Regional hydrology, extent of water development activity, and primary use of water were the most evident factors related to differences in minimum streamflow discrepancies among States.

Analysis of upstream flow data for six projects indicated that low upstream flows correlated with a high proportion (over 50 percent) of minimum streamflow discrepancies and that low inflows may be a particularly chronic situation in parts of Colorado and Wyoming. It was difficult to assess whether low upstream flows were a primary factor contributing to non-maintenance of minimum streamflows for projects without upstream gages, but subjective information from State and FWS personnel and project operators indicated that low inflows may be an important consideration.

Additional factors contributing to minimum streamflow discrepancies included obscure language in the agreements, misinterpretation of the agreements, and lack of project monitoring. Factors causing temporary but not consistent reductions in flow releases included mechanical shutdowns due to power outages, construction, repair and maintenance work, and emergency situations (e.g., flow releases reduced to prevent downstream flooding).

Few projects were identified that would be suitable to evaluate the biological effectiveness of minimum streamflow releases. Potential candidates included projects located on headwater streams and existing projects that recently implemented minimum flow releases. Factors to consider when selecting projects for evaluation include the following.

1. Are pre- and post-development data available, and are the data comparable? Or, for an alternative approach, are data available before and after minimum streamflow releases were implemented downstream from existing projects?

2. What was the original objective of the minimum streamflow release?
3. What are the extent and nature of upstream impacts?

4. Has any stream habitat improvement work been implemented that would make it difficult to isolate ecological responses to altered streamflows?

Lack of streamflow data and lack of project monitoring were identified as two important factors that decrease the effectiveness of formal streamflow agreements. Without appropriate flow data and regular monitoring it is impossible to evaluate compliance or factors contributing to lack of compliance, or identify appropriate solutions.

While Federal agencies have the authority to review water developments and require mitigation to protect resources, the responsibilities for monitoring and enforcement have not been well defined or carried out. States are responsible for managing fish and wildlife populations; thus, somewhat by default, the State fish and wildlife agencies have been relied upon to monitor these projects. However, the States do not have the manpower or funds to establish a regular "monitoring program," nor may the State agencies be aware of all the projects that exist with Federal permits having minimum streamflow conditions. The result is that some projects may be "monitored" on a frequent basis due to the quality of the fishery and public popularity, while other projects are rarely "monitored." Furthermore, while the States may be able to monitor on an infrequent basis, they do not have the enforcement authority; thus, responsibility falls back to the Federal permitting agency.

Projects with flow agreements were identified but compliance with specific conditions of the agreements (i.e., permits and licenses) could not be evaluated due to lack of sufficient data. Almost half of the stream locations with instream flow agreements that were identified in this study did not have daily streamflow records. In addition, the majority of flow agreements condition the minimum release by allowing the inflow to the project to be released when upstream flows are below the specified minimum amount. Presently, compliance with this type of condition rarely can be evaluated due to the lack of upstream flow data. Many projects do not have the funds to install downstream gages, much less an additional gage upstream from the project. Likewise, deleting the "inflow can equal the outflow" exception creates a serious conflict with the principles under which most projects operate. Many project operators do not believe they are obligated to release storage water to maintain agreed-upon minimum flows if inflows to the project are less than the agreement. In addition, if storage water is obligated for other uses with existing water rights, there may be legal constraints to releasing water for an unappropriated use. An expensive alternative is for the State or a Federal agency to purchase storage water to augment downstream flows for nonconsumptive uses (e.g., Boulder Lake Reservoir, Wyoming, and Painted Rocks Reservoir, Montana).

Conditions of streamflow agreements that depend on storage requirements are also difficult to evaluate because appropriate data are not available. These situations require close cooperation between the developer and fish and wildlife agencies, and the cooperative effort should be established in the agreement to insure its effectiveness.

Another factor that hinders evaluation of streamflow agreements is the poor documentation of the negotiating and decision-making processes. Many agencies, both Federal and State, can be involved in the review of projects and the final decisions concerning streamflows. The effort required to track individual projects through this process is time consuming and results in numerous information gaps. Negotiations often take place behind closed doors and are not documented; thus, the rationale behind a final streamflow agreement is lost. Documentation is particularly important due to the diversity of instream flow methodologies that are available. The agreed upon streamflow may be a result of one particular methodology, a synthesis of multiple methodologies, or negotiations using the flows determined by instream flow studies as guidelines. In addition, information concerning the goals of the various agencies involved in streamflow determinations (i.e., streamflows for channel maintenance, or a specific fish species or habitat type, etc.) can be difficult to determine because they are not documented. Without documentation, factors such as these, which may be important in influencing the success of an agreement, cannot be evaluated.

In conclusion, the institutional responsibilities for monitoring and enforcement need to be clearly established and implemented for formal streamflow agreements (i.e., streamflow conditions in Federal permits and licenses) to be effective. This would alleviate some of the problems associated with lack of streamflow data since agreements often require operators to install gages or make data available to the appropriate agencies, yet without monitoring and enforcement these conditions may not be met. Furthermore, a concerted effort to establish a comprehensive information system, including documention of the decision-making process, would aid State and Federal agencies in identifying and monitoring water development projects.

LITERATURE CITED

Bean, M. 1983. The evolution of national wildlife law. Praeger Publishers, New York. 449 pp.

Bovee, K. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. U.S. Fish Wild. Serv., Instream Flow Information Paper No. 12. 248 pp.

Brown, R., T. Richardson, G. Taylor, and R. Guinee. 1986. Follow-up observations and analysis of some small hydroelectric projects exempted from licensing by the Federal Energy Regulatory Commission (FERC). Sacramento, California. U.S. Fish Wild. Serv., Div. Ecol. Serv. Field Office Report. 18 pp.

Federal Energy Regulatory Commission. 1986. Unpublished report. Federal Energy Regulatory Commission, Washington, D.C.

Fifer, S. 1980. Water law and National Forest Management. U.S. Forest Service, White River National Forest, Glenwood Springs, Colorado.

Fraley, J., and P. Graham. 1982. The impact of Hungry Horse Dam on the fishery of the Flathead River, Final report. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 91 pp.

Gardner, W., and R. Berg. 1982. An analysis of the instream flow requirements for selected fishes in the wild and scenic portion of the Missouri River. Montana Department of Fish, Wildlife and Parks, Great Falls, Montana. 110 pp.

Hazel, C. 1976. Assessment of effects of altered stream flow characteristics on fish and wildlife. Part B: California. Final report. U.S. Fish Wild. Serv. FWS/OBS-76/33. 65 pp.

Interagency Instream Flow Task Force. 1979. Identification of existing federal water resources development projects where instream flow uses could be improved. Washington, D.C.

Karl, T., and R. Knight. 1985. Atlas of monthly Palmer hydrological drought indices (1931-1983) for the contiguous United States. National Climatic Data Center, Historical Climatological Series 3-7, Asheville, North Carolina.

Leathe, S., and F. Nelson. 1986. A literature evaluation of Montana's wetted perimeter inflection point method for deriving instream flow recommendations. Montana Department of Fish, Wildlife and Parks, Helena, Montana. 69 pp.

Marotz, B., and J. Fraley. 1986. Instream flows needed for successful migration, spawning and rearing of rainbow and westslope cutthroat trout in selected tributaries of the Kootenai River, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 121 pp.

Montana Department Fish, Wildlife and Parks. 1979. Instream flow evaluation for selected streams in the Upper Misssouri River Basin. Montana Department of Fish, Wildlife and Parks, Helena, Montana. 254 pp.

Nelson, F., and L. Peterman. 1979. Determination of instream flows in Montana: an action plan. Montana Department of Fish, Wildlife and Parks, Helena, Montana. 64 pp.

Nelson, W., G. Horak, M. Lewis, and J. Colt. 1976. Assessment of effects of altered stream flow characteristics on fish and wildlife. Part A: Rocky Mountains and Pacific Northwest. Final report. U.S. Fish Wild. Serv. FWS/OBS-76/29. 129 pp.

O'Connor, J. 1985. An overview of FERC's small hydropower licensing program. Symposium on small hydropower and fisheries. American Fisheries Society, Bethesda, Maryland.

Roelle, J., and D. Hamilton. 1985. A strategic plan for evaluating FWS mitigation activities. U.S. Fish Wild. Serv. WELUT-86. 41 pp.

Tennant, D. 1976. Instream flow regimes for fish, wildlife, recreation and related environmental resources. Fisheries 1(4):6-10.

Trihey, E., and D. Wegner. 1981. Field data collection procedures for use with the physical habitat simulation system of the Instream Flow Group. U.S. Fish Wild. Serv. Cooperative Instream Flow Service Group. Fort Collins, Colorado. 151 pp.

U.S. Army Corps of Engineers. 1985. Regulatory guidance letter to the chief engineers. 2 May 1985.

U.S. Army Corps of Engineers. 1984. Libby Dam and Reservoir, Kootenai River, Montana. Water Control Manual. Army Engineer District Corps of Engineers, Seattle, Washington.

U.S. Bureau of Reclamation. 1984. Colorado River storage project. U.S. Government Printing Office, Washington, D.C. 6 pp.

U.S. Fish and Wildlife Service. 1985. Hydropower follow-up study. U.S. Fish Wild. Serv., Habitat Resources Program, Newton Corner, Massachusetts. 13 pp.

U.S. Geological Survey. 1968. Water resources investigations in Colorado (Map). U.S. Geological Survey, Water Resources Division.

U.S. Geological Survey. 1982a. Water resources investigations of the U.S. Geological Survey in Montana (Map). U.S. Geological Survey, Reston, Virginia.

U.S. Geological Survey. 1982b. Water resources investigations of the U.S. Geological Survey in Wyoming (Map). U.S. Geological Survey, Reston, Virginia.

U.S. Geological Survey. 1984. Surface-water and related land resources development in the United States and Puerto Rico (Map). U.S. Geological Survey, Reston, Virginia.

Viessman, W. Jr., J. Knapp, G. Lewis, and T. Harbaugh. 1977. Introduction to hydrology (2nd ed.). Harper and Row Publishers, New York. 704 pp.

Wesche, T., and P. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. Eisenhower Consortium for Western Environmental Forestry Research, Bulletin 9. Available from U.S. Government Printing Office, Washington, D.C. 122 pp.

White, M., F. Valdez, and M. White. 1980. Instream flow negotiation: review of practices. U.S. Fish Wild. Serv. FWS/OBS-80/53. 50 pp.

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All known water projects in Colorado, Montana, and Wyoming with streamflow agreements and data on streamflows below the project were examined to assess the frequency of discrepancies between agreed-to and actual flows. A total of 73 water development projects were identified, involving 119 locations with minimum streamflow agreements. Of the 119 locations, only 61 had streamflow data. Of these 61 locations, 54 exhibited flows below those established in streamflow agreements on at least some occasions; 28 locations had flows 25% of the established agreement or less. Several locations showed chronic deviations. Actual flows were lower than agreed-to flows for 20% or more of the time at 17 of the 61 locations. These data are summarized by State, agency, and type of agreement in the main report. An appendix (bound separately) presents detailed data on each of the water development projects examined.

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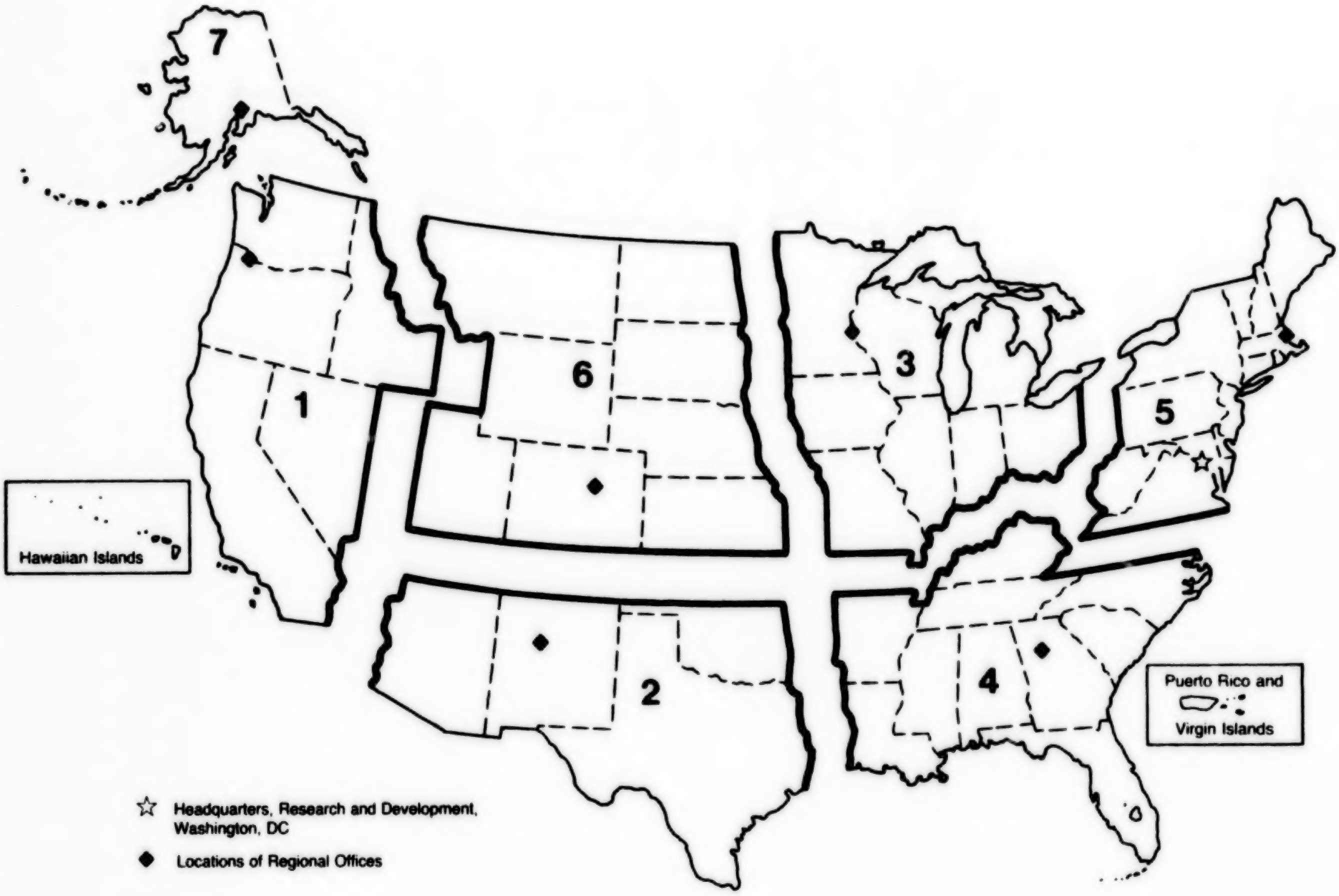
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